Possibilities of Gasification and Pyrolysis Technology in Branch of Energy Recovery from Waste

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Summary

The article summarizes possibilities of energy recovery from waste (first of all from municipal waste and tyres). Attention is given to technologies which can be, besides classical grate boilers, used for energy recovery from waste. These include gasification and pyrolysis units. There are emission values that were measured on the pyrolysis equipment of a new construction. The equipment is being prepared for practical use at present. The equipment more or less fulfils both emission limits valid in the Czech Republic and the emission standards of the European Union. The conclusion of this contribution is devoted to the current and future situation in the area of energy recovery from waste in the Czech Republic

Keywords: waste, energy recovery, gasification, pyrolysis

Introduction

During the energy recovery from municipal waste in modern grate boilers or furnaces is assumed for cleaning the flue gas to use a combined method [1, 2], consisting of the following basic steps (spray drying reactor, fabric filter, three-stage flue gas scrubber and SCR method - DeNOx and DeDiox catalytic reactor) [3].

The SCR reactor is equipped with a catalyst, whose active ingredients are oxides of vanadium (vanadiumpentoxid - V_2O_5) and tungsten (wolframtrioxid - WO_3) on a titandioxid carrier (TiO_2) in ceramics. These will allow oxidation of dioxins and furans (PCDD/F) at the temperature of around 150°C to 220°C (otherwise PCDD/Fs decompose without the presence of a catalyst at temperatures above 850 °C – the SNCR method). Dioxins and furans oxidatively decompose into trace amounts of hydrogen chloride (it can be washed in a wet flue gas treatment), water vapour and carbon dioxide [3, 4].

To reduce NOx, the catalytic reactor must have an appropriate temperature (240°C – see above) and spraying the NH_3 solution before the catalyst must be ensured. In this way, the nitrogen oxides decompose into nitrogen and water.

In fact, the emission concentrations of dust particles from incinerators into the air range at one-tenth of the permitted limits, and incinerators emit in the air less TOC and PCDD/F than enter them with the waste or the combustion air. Also other emissions of incinerators are lower than those occurred in producing an equal amount of energy in conventional combustion sources [4].

Despite the above mentioned facts, it is often required (especially within the process of environment impact assessment – EIA) to compare this “classical equipment” with such equipment that has not been sufficiently used in the Czech Republic or the other countries of the European Union. This especially includes gasification of waste and pyrolysis.

Gasification of Waste

The essence of gasification is the conversion of carbonaceous materials at higher temperatures (above 800°C) into combustible gaseous substances under the supply of under-stoichiometric amount of air or other oxidising agent. The gasification is a strongly endothermic process. The advantage is that due to the high temperatures there are no problems with the formation of toxic dioxins, furans and polycyclic aromatic hydrocarbons. The reducing environment prevents the formation of nitrogen oxides [5].

The gasification is partial combustion of organic compounds forming gases which can be used as a raw material (using reform processes) or as a fuel. The gasification processes are suitable for the treatment of municipal waste, some hazardous waste and dried sewage sludge.

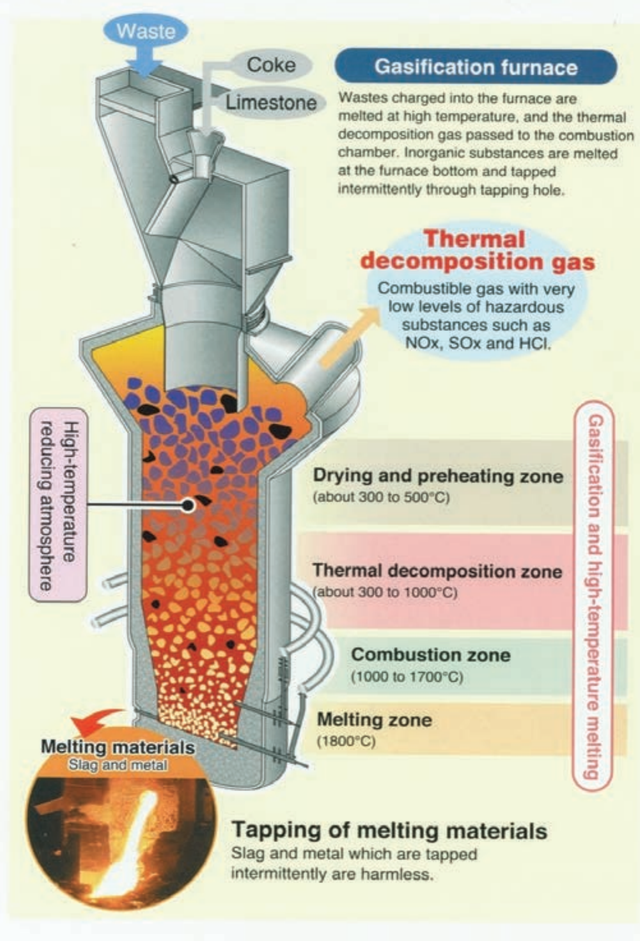

Fig. 1 Kazusa Clean System – a gasification and melting furnace [6]
Rys. 1 Kazusa Clean System - piec do zgazowania i wytopu [6]

It is necessary to note that gasification of waste has recently been developed and implemented to a great extent in Japan.

Very interesting structures are e.g. gasification units working in the plant for energy recovery from municipal waste of the company Kazusa Clean Systems Co., Ltd. The plant was built in Kisarazu City, in the Japanese Prefecture of Chiba, by the firm Nippon Steel Engineering Co., Ltd. (see Fig. 1) [6].

In the gasification furnace, the temperature of up to 1,800°C is reached in the melting zone (here municipal waste is melted in the last phase), while the leaving slag is granulated in a water trough and then crushed. From the slag, metals are obtained by magnetic separation, and the rest is used in civil engineerEng.

The gas comes into the combustion chamber, where it is burned. Flue gases are fed to the waste heat boiler which produces superheated steam driving the turbine and the generator, producing electricity. Units are available with a capacity of 100 or 125 tonnes of municipal waste per day. The company Kazusa Clean Systems Co., Ltd. has 2 units in place for processing 100 tonnes of municipal waste per day and 2 units for processing 125 tonnes of municipal waste per day. The output of the generators is then 3,000 kWe and 5,000 kWe [6].

Flue gases are cleaned in a multistage process as is the case of the *Plant for energy recovery from municipal waste Malešice (ZEVO Malešice)*, including the SCR - the DeNOx and DeDiox catalytic reactor.

Pyrolysis

Pyrolysis is the thermal decomposition of organic materials in the absence of oxygen-containing media (air, carbon dioxide, water vapour) which leads to the formation of gaseous, liquid and solid fractions. This process is an alternative to combustion.

The essence of this method is that organic compounds are less stable at higher temperatures. High molecular substances are decomposed to low molecular ones, which leads to their breakdown into volatile products and coke. Pyrolysis is carried out at the temperatures ranged from 150°C to 1,000°C. According to the temperatures, we distinguish:

- Low-temperature pyrolysis (reaction temperature up to 500°C),
- Medium-temperature pyrolysis (reaction temperature from 500°C to 800°C),
- High-temperature pyrolysis (reaction temperature above 800°C).

Advantages of pyrolysis processes [7]:

- Easier and less capital-intensive plants,
- Produced fuels are easily merchantable, than heat and steam,
- There is only a small fraction of gaseous products of incineration compared to the same amount of fuel.

Disadvantages of pyrolysis processes:

- More expensive operation,
- A problem to remove the pyrolysis residue (pyrolysis coke), liquid hydrocarbons, containing a high content of heavy metals.

Pyrolysis can be used in addition to the thermal treatment of municipal waste and sewage sludge also to:

- Decontamination of soils,
- Treatment of plastic waste and used tires,
- Treatment for the substance utilization of cable waste, metal and plastic materials.

For a long time, the gasification and pyrolysis are considered to be very promising also in the field of energy recovery from waste. Although research in this area is quite wide and technological development is well advanced, neither of these technologies is still established in the waste area so that the future operator in the Czech Republic could get it complete, as we say "turn-key". This is currently a big problem, because there is nothing in this field in the Czech Republic the entrepreneurs could equipped with the intended operations for treatment of waste (municipal waste, tires) that they would like to operate as a plant for waste energy recovery [4].

Nevertheless, one piece of equipment available for tyre processing (applicable also other types of waste) is a pyrolytic line M3RP supplied by AmbientEnergy LLC (USA) and made by SCOGEN (India) [8]. Another facility sold as PTR (= engl. STD - slow thermal decomposition) is from Czech firm HEDVIGA GROUP plc and it is capable of energy recovery from waste rubber, tyres and municipal waste as well as a whole number of other waste (sewage sludge, oil waste, plastics, biomass) [9].

The PTR principle (= STD – slow thermal decomposition) is based on the principles of pyrolysis, however it is modified. Unlike the standard pyrolysis process, the qualitative technical and technological shift with the PTR technology is the following [9, 10, 11]:

- it is low-heat decomposition with the temperature below 480°C with a higher efficiency of energy use for heating without chimney waste,
- it is a slow process (slow thermal decomposition); thermal decomposition has therefore sufficient time (in terms of tens of minutes) for a complete separation of fractions and consequently for a higher efficiency of creation of gas and liquid products. The yield on these products from comparable raw materials is about 5 ÷ 8 % higher than bibliography mentions (measured for decomposition of tyres at the temperature of up to 480°C),
- the process starts with slow heating in terms of minutes when fine separation of fractions happens without formation of crust on the surface,
- it is a Batch process which itself is not continuous, therefore the slowness of the process allows a complete separation of products and control of the temperature increase in the raw material according to temperature curve without thermic shock,
- the slowness of the process allows to collect all gas products into tanks and to use them to operate a cogeneration unit without discharging exhaust gases into the air. As a result, no emissions happen (except the outlet from the cogeneration unit).

The PTR unit consists of two modules: the thermal (heating – see Fig. 2) and the cooling one. Both modules have a shape and size of a 20-foot transport container for the capacity of 1 ton per hour.

The thermal module (Fig. 2) is built on the basis of an electric chamber furnace with side heating by resistance bars and a maximum input of 200 kW. The furnace is bricked with fireclay bricks in the floor and heat insulation on the basis of fibreglass in the walls. In the upper part of the furnace there are three ventilators allowing for stable heat convection and speed of flowing around fuel elements. Raw material is put

Fig. 2 Pyrolysis plant PTR 1000 (HEDVIGA GROUP plc) – thermal module [10, 11]
Rys. 2 Instalacja do pirolizy PTR 1000 (HEDVIGA Group plc) - moduł termiczny [10 , 11]

in the furnace in steel compartments, fuel elements made of stainless steel of the class 17 with the thickness of the wall of 5 ÷ 10 mm with three outlets for gas products and with bayonet valves for raw material in the upper and side part of the element with the diameter of 50 ÷ 80 cm with insulation that prevents air from getting into the compartment. The fuel element is transported to the furnace on rails. As to the manipulation with fuel elements, the PTR unit needs 8 fuel elements for its operation, two being in the furnace, two in the exchanger, two being cooled and two being filled.

Fuel element is filled from the top with ground raw material which is transported from the mill by means of a conveyor belt. The element is manipulated by a radial crane which places it on the rails in front of the furnace. The element enters the furnace (the thermal module) on the rails. After finishing a cycle, the hot element is pulled out on the rails by means of a magnetic lock and is then left in a thermal exchanger with a newly filled element. After cooling (approx. 6 hours), the element is lifted by a crane and the carbon rest is dumped into a container.

The cooler of the PTR process is placed in a 20-foot container and has two circuits with a total length of 84 metres. Each circuit of the cooler is attached individually on one fuel element. The input temperature of gases entering the cooler is on average 450°C and the output temperature is 80°C. The cooling liquid is water with ethyleneglycol (in a closed circuit). Hydrocarbons and oil fractions condense in the cooler and pyrolysis oil occurs. Its composition depends on the composition of the raw material. Oil from the process is accumulated at the outlet of the cooler in its bottom part. The gas is subsequently treated, i.e. dried and purified [9, 10, 11]

The weight balance of the fraction production from the PTR 1000 process differs according to the raw material: approx. 330 kg of gas, 450 kg of pyrolysis oil and 220 kg of the carbon rest is produced from 1,000 kg of tyres (raw material).

The technology is connected with the TEDOM Cento T 180 (Czech Republic) cogeneration unit which produces heat and electric current from the formed pyrolysis gas. The oil and solid outputs from the technology may be used as fuel and will be subject of commercial sale.

An example (see Tab. 1) gives emission values of pollutants which were recorded during one of the first measurements [12] carried out on the PTR 1000 equipment from the company HEDVIGA GROUP plc during pyrolysis of tyres. The emission values suggest that the PTR 1000 equipment fulfils the emission limits valid in the Czech Republic as well as the emission standards of the European Union.

Closing Remarks

In the Czech Republic in 2020 it will be necessary to operate the plants for energy waste recovery with a total annual processing capacity of 2.0 million tonnes of mixed municipal waste (MMW). With an average calorific value of mixed municipal waste of about 10 MJ/kg, we obtain (in the Czech Republic) at least 20 million GJ of energy (potential energy) per year through the energy recovery of that amount of waste [13].

The capacity of three big municipal waste grate incinerators in our country (ZEVO Praha-Malešice,

Tab. 1 Measured emission values – pyrolysis of tyres. Pyrolysis plant PTR 1000 (manufacturer HEDVIGA GROUP plc, Vratimov, Czech Republic)

Tab. 1 Zmierzone wartości emisji - piroliza opon . Instalacja do pirolizy PTR 1000 (producent HEDVIGA Group plc, Vratimov, Czechy)

Parameters	Average values	Emission limits	Remarks
NO_x	424 mg/Nm^3	500 mg/Nm^3	Emission limits for cogeneration units (CR)
CO	104 mg/Nm^3	650 – 1300 mg/Nm^3	Emission limits for cogeneration units (CR)
TZL (total dust)	0,55 mg/Nm^3	10 mg/Nm^3	Emission limits for incineration of waste (CR)
HF	0,09 mg/Nm^3	1 mg/Nm^3	Emission limits for incineration of waste (CR)
HCl	1,85 mg/Nm^3	10 mg/Nm^3	detto
PCDD/F (Σ TEQ)	0,0307 mg/Nm^3	0,1 mg/Nm^3	detto
Hg metals	0,01600 mg/Nm^3	0,05 mg/Nm^3	detto
Cd metals	0,00088 mg/Nm^3	0,5 mg/Nm^3	detto
PAH	0,813 mg/Nm^3	1 mg/Nm^3	Emission limit (EU)

SAKO Brno, and TERMIZO Liberec) is about 600 thousand tonnes of waste (MMW) per year. The use of selected and modified municipal waste in cement plants through the gasification and in biogas stations is about 350 thousand tonnes per year.

Thus, from 2 million tonnes, 600 thousand tonnes can be processed in existing incinerators, in the three planned incinerators another 400 thousand tonnes, and in other energy waste recovery plants, 350 thousand tonnes of municipal waste. To the year 2020, about 650 thousand tonnes of mixed municipal waste still remains, which we will not be able to put on landfills and which it would be able to be processed e.g. in pyrolysis facilities.

As it has been mentioned above, the research in this field is quite extensive and the technological development has made a considerable progress. However, very little from these technologies has been implemented in the area of waste to encourage future operators to use it immediately. Also, it is important to make it work properly. This is currently a big problem, because there is nothing in this field in the Czech Republic the entrepreneurs could equipped with the intended operations for treatment of waste (municipal waste, tyres) that they would like to operate as a plant for waste energy recovery.

Often, citizens and representatives of civic associations talk about the need to prefer new technologies (first of all gasification or pyrolysis) for energy recovery from municipal waste, tyres, and other waste (waste rubber, sewage sludge, oil waste, plastics, biomass) and not consider the use of such grate incinerators, although at the output equipped with plants for treatment flue gases at the highest possible technical level. Certainly, it is appropriate to introduce new innovative technologies. However, it should be pointed out that e.g. the plant for gasification of municipal waste shall be equipped with the same equipment for flue gas treatment (see above the plant of the firm Kazusa Clean Systems Co., Ltd.), as is in grate incinerators equipped with the plant for capturing pollutants at the highest level. Then, of course, it is debatable whether it is necessary at any cost to seek to build often more expensive and technologically complex plant, when securing the air protection is assured in both cases practically by an identical capturing plant.

In case of energetic use of tyres, municipal waste or other waste in pyrolysis facilities, the situation is different. It is not necessary to attach these facilities with additional equipment for flue gas treatment (see the above recorded values in Tab. 1).

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Streszczenie

Artykuł podsumowuje możliwości odzysku energii z odpadów (przede wszystkim z odpadów komunalnych i opon).Uwagę zwrócono na technologie, inne niż klasyczne stosowane kotły rusztowych, stosowane do odzysku energii z odpadów. Należą do nich instalacje zgazowania i pirolizy. Przedstawiono wartości emisji , które zostały zmierzone w urządzeniu do pirolizy nowej konstrukcji. Aktualnie instalacja jest przygotowana do wdrożenia praktycznego. Instalacja spełnia limity emisji zarówno w Czechach jak i normy emisji Unii Europejskiej . Celem artykułu było kierunków rozwoju technologii odzysku energeii z odpadów w instalacjach w Republice Czeskiej.

Słowa kluczowe: odpady, odzysk energii, zgazowanie, piroliza