WASTE TREATMENT BY PLASMA TECHNOLOGY

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Abstract

The article points to the advantages and disadvantages of waste incineration and plasma melting and gasification. More is described the methodology of waste treatment by plasma technology.

Key words: municipal waste, plasma technology, waste incineration.

INTRODUCTION

Under the Article 13 of the Directive of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives 2008/98/EC requires Member States to take the necessary measures to ensure that waste management is carried out without endangering human health and without harming the environment, i.e., in particular [1]:

a) without risk to water, air, soil, plants or animals,
b) without causing a nuisance through noise or odours, and
c) without adversely affecting the countryside or places of special interest.

PRODUCTION AND WASTE MANAGEMENT

The total annual of waste production in the European Union, according to the latest data from Eurostat, in 2012 amounted to about 2.3 billion tons. From the produced waste (Fig. 1) was deposited on landfills approximately 973.5 million tons [2].

EU policy in the context of waste management is mainly focused on:

- preventing the creation of waste,
- minimizing the quantity of waste,
- creating the conditions for recovery of waste as a source of secondary raw materials and energy.

INCINERATION OF WASTE vs. PLASMA TECHNOLOGY

Incineration of waste leads to the production of CO₂ (carbon dioxide), which contributes to the creation greenhouse effect (though with a lower climate impact than methane). The product of incineration of municipal waste (MW) is fly ash and slag. This homogeneous waste constitutes about 25 – 30% of the original weight of MW and approximately 10 – 15% of the original volume of waste.

Some parts of the slag composition and fly ash form the toxic substances. We achieve a significant reduction of the landfilling area with combustion, but this type of waste is deposited in landfills with controlled mode. [3]. Incineration of waste in the EU is governed by Directive of the European Parliament and Council of 4 December 2000 on the incineration of waste.

Tab. 1 contains the advantages and disadvantages of waste incineration.

<table>
<thead>
<tr>
<th>Advantages of waste incineration</th>
<th>Disadvantages of waste incineration</th>
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<tbody>
<tr>
<td>- significant volume reduction of landfilling solid waste,</td>
<td>- incineration emits excluding carbon, nitrogen, sulphur, heavy metals also a few dozen of the 210 substances collectively known as dioxins and furans,</td>
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<tr>
<td>- the part of hazardous substances is removed or retained in effective filters,</td>
<td>- hazardous gases are brought to the air with incomplete cleaning of combustion gases.</td>
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<td>- produced heat is useful for heating or electricity generation.</td>
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Plasma treatment is a method for disposal of waste, which cannot be recycled. The difference between plasma waste treatment and waste incineration is primarily in the operating temperature of waste disposal. Temperatures about 800 – 900°C are typical operating temperatures for waste incinerators. Plasma treatment
of municipal waste (MW) is carried out at temperatures about 1400 - 1600 °C.

Technology ensures:

a) the destruction of the molecules of organic substances,
b) the melt of inorganic waste fractions.

The next tab. 2 includes the advantages and disadvantages of plasma waste treatment.

Tab. 2 Advantages and disadvantages of plasma waste treatment [5]

<table>
<thead>
<tr>
<th>Advantages of plasma waste treatment</th>
<th>Disadvantages of plasma waste treatment</th>
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</thead>
<tbody>
<tr>
<td>- heterogeneous dose with minimal modifications,</td>
<td>- high energy consumption,</td>
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<tr>
<td>- conversion of carbon is almost 100% (at optimum ratio of C:O in the reaction chamber),</td>
<td>- source of energy is electricity, so plasma technology is economically costly (compared with incineration).</td>
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<tr>
<td>- product of technology is vitrified (glassy) slag and synthesis gas,</td>
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<td>- support the &quot;3Rs&quot; principle for waste management – reduce, reuse, recycle,</td>
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<tr>
<td>- waste from technology is in form of vitrified slag (small volume) and in form of undesired components from synthesis gas,</td>
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<tr>
<td>- significantly lower emission values to the limit values affecting the environment (analysis of the data given in the scientific literature).</td>
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METHODOLOGY OF PLASMA WASTE TREATMENT

The process of plasma waste treatment consists of 3 basic steps:

1. analysis of dosed material,
2. treatment process,
3. analysis of products.

1. Analysis of dosed material

Plasma treatment process is preceded by an analysis of dosed waste fractions.

The following graph (Fig. 2) contains the average composition of municipal waste.

Fig. 1 The average composition of mixed municipal waste (wt. %) [6]

2. Treatment process

Mixed municipal waste is processed in a reducing atmosphere of plasma reactor. The laboratory plasma reactor with a dependent arc uses N₂ as a plasma gas. Plasma gas is supplied to the reaction chamber for:

- forming the plasma arc discharge through the hollow graphite electrode,
- sealing purposes.

The waste is dosed to reaction chamber in several seconds intervals. It ensures the optimal operation mode in terms of the plasma arc existence. Longer duration of dosing and larger amount of dose would cause the loss of the plasma arc.

First the pyrolysis (thermal cleavage) arises in the plasma process. During the pyrolysis the complex of organic substances are cleaved into simpler substances of hydrocarbon type. Further reaction is partial oxidation to form the CO from the oxygen, which is contained in waste. Also is produced a small amount of CO₂ (depending on the ratio of atoms C:O which supplied to reaction) and water vapour (from the humidity of dosed waste). Both of these substances reduce the heating value of synthesis gas. It is therefore the effort to lead the process such a way that oxidation reaction of C + O₂ = CO₂ is created minimal. The synthesis gas at the outlet of the reactor reaches a temperature of 800 – 1 100°C [7].

3. Analysis of products

As mentioned above, the plasma treatment causes the decomposition of organic substances on the simplest gas dissociation fragments, so-called synthesis gas such as H₂, CO, N₂ etc. This gas is transferred into gas treatment device, where the contaminants must be removed. It is avertting the possible damage of the combustion device – i.e. combustion turbine, the steam generator boiler or cogeneration unit.
The remaining non-biodegradable components (metal, glass, soil and other inorganic materials) in a molten state are collected in the bottom of the reactor and from there are pouring into a mold. Solid residues are divided after removal from the molds into two parts:

- metal alloy, which is useful in metallurgy;
- glassy (vitrified) inorganic slag, which represents an inert material.

Fig. 3 Molds casting and the vitrified slag

**CONCLUSION**

Plasma technology is suitable for processing a wide range of materials (with the exception of high-level radioactive waste), for example municipal solid waste, industrial waste, hospital waste, toxic and hazardous waste or chemical solvents, heavy metals, fly ash, ash from MW incinerators, asbestos fibers, sludge from sewage treatment plants, used tires, etc. [8].

Plasma gasification and melting process is more appropriate way to dispose the waste, based on current knowledge of the thermal treatment of waste. The result of this process is:

- significantly lower load on the environment with emissions of NO\textsubscript{x} and SO\textsubscript{x} (observing optimal boundary conditions),
- using the energy potential of waste (synthesis gas),
- recycling the metal components in waste,
- using the environmentally acceptable slag (transport engineering) [9].

**References**


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