1. General

Pyrolysis is the method during which natural and chemical decomposition of the thermally unstable organic substances included in waste is taking place under temperature in the area of 400 - 800°C, with the absence of air or O_2. The great difference of pyrolysis comparing with incineration and gasification is that it is a highly endothermic process and requires outer energy source so as to take place. In fact, it is difficult to have conditions of complete absence of O_2, so in practice pyrolytic systems are operating with oxygen quantities less than the stoichiometric ones.

The reactions that are taking place are initially decomposition ones, when organic constituents characterized by low volatility are converted into other more volatile substances:

$$C_xH_y \rightarrow C_cH_d + C_mH_n$$

Furthermore, in the primary stages of the pyrolysis stage condensation reactions, hydrogen removal reactions and reactions forming rings are taking place that lead to the formation of a solid residue containing carbon from organic substances of low volatility:

$$C_xH_y \rightarrow C_pH_q + H_2 + \text{coke}$$

Then, other reactions of the organic pollutants occur. In the case of O_2 existence, CO and CO_2 are formed or the interaction with H

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O is possible. The produced coke can be gasified into O

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and CO

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The pyrolysis products can be liquid, solid or gaseous. The exact amounts depend on the nature of the waste to be treated, the heating conditions, the temperature and the treatment duration (contact time) (Institution of Mechanical Engineers, 2007; Gidarakos, 2006).

The main advantages of pyrolysis comparing to incineration include the following:

- The decomposition temperature is much lower than that of incineration.

- The decomposition is taking place in reducing atmosphere and not oxidizing one, like in the case of incineration. The requirement for lower O 2 quantity also results in limited air emissions.
- The content of ash in C is much higher than in the incineration.
- Metals included in waste are not oxidized during pyrolysis and, therefore, can be exploited more easily.
- The combustion of the pyrolysis gas does not produce ash and the cleaning process of the off-gasses is easier.
- The initial waste volume is reduced at higher degree comparing with incineration.

The main disadvantages of pyrolysis include:

- The biggest problem of pyrolysis is that the waste to be treated has to be cut down in small pieces sorted prior to the pyrolysis process and this can substantially increase the cost for the installation and operation of pyrolysis units.
- The pyrolysis products have certain problems and in no case they can be disposed at the environment as they are.
- The systems for the cleaning of the generated gases and wastewater are characterized by high cost.
- At present, the application of the method at full scale is very limited.

The pyrolysis method has several different variations, one of which is thermolysis.

2. Mass and energy balances

A typical mass balance of the pyrolysis process is shown in Figure 1. On the basis of this diagram it can be stated that 1 tonne of treated carbon-based materials of Municipal Solid Waste (MSW) produces 380 kg syngas, 220 kg wastewater, 240kg char, while the remaining 150kg are other residues (metals, inert, salt).

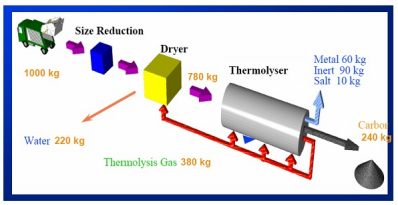

Figure 1: Pyrolysis process flow chart

Considering the complexity of biomass composition, pyrolysis and the absence of the thermodynamic parameter, it is difficult to determine the conversion of energy. In general it can be considered:

$Q = CP\Delta T + QP,$

where Q is absorption of heat during pyrolysis process, $kJ \cdot kg^{-1}$,

CP is specific heat capacity of substance, $kJ \cdot (kg \cdot K)^{-1}$,

ΔT is change of temperature,

QP is enthalpies of reactions during the process, $kJ \cdot kg^{-1}$.

The proposed energy balance model equation is described below: For 1,000kg feedstock, 320kg biomass fuel is needed. The Lower Heating Value (LHV) of the biomass and biomass fuel is 3,900 $kcal \cdot kg^{-1}$ and the LHV of the process products is as follows:

- The output of the gas is $250m^3$, Lower Heating Value (LHV) is $15.18MJ \cdot m^{-3}$
- The output of the charcoal is 300kg and its Lower Heating Value (LHV) is 7,100 $kcal \cdot kg^{-1}$ (WASTESUM, 2006).

3. Market potential for products

The pyrolysis gas produced from the pyrolysis process can be utilized in boilers, gas turbines or internal combustion engines in order to generate electricity, while part of the pyrolysis ash can be used for manufacturing brick materials.

4. Environmental impacts

The environmental impacts of the pyrolysis process focus on air emissions and solid residues, as in all thermal technologies. Due to the high temperatures used in pyrolysis, toxic metals including cadmium and mercury, acid gases including hydrochloric acid and ozone-forming nitrogen oxides can be released. On the other hand, pyrolysis enables fossil fuel substitution by the MSW and, in addition, slow pyrolysis may stabilize a portion of the C in these effects of biochar remain for 10 years after initial application. Furthermore, the methane emissions produced from the disposal of MSW to landfill sites are reduced.

5. Economic data

According to the Carbon Finance Unit of the World Bank in 2008, the capital cost of a gasification system with a capacity of 70-270 tonnes per day is 30-60 € /tonne, while the operation and maintenance cost is 55-100
€
/tonne. In general, the application of the pyrolysis process can be considered viable for smaller waste quantities in relation to incineration.

6. Applicability in the target area

Pyrolysis is one of the innovative thermal waste management methods with limited application in full scale. The majority of the existing pyrolysis units in operation are pilot ones. This is the main reason why it is not expected soon to have this option available in the Balkan Region within the near future. Nevertheless, it is expected that there will also be some developments in this field later, perhaps next decade. The relevant cost is considered as preventive factor for the development of such systems for Romania, Bulgaria, Greece and Slovenia for the time being.

References

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