Replacement of Incineration by Steam-Gasification

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High temperature processing of waste is usually performed by oxidation of the waste components with atmospheric oxygen. It may be aimed to recovery of energy or / and recovery of materials. We would like show that the atmospheric oxygen may be successfully replaced by steam in incineration of a fraction of MSW.

Keywords: municipal solid waste ; steam gasification ; thermochemical cycle

Background

Considering gasification, a variety of processes may be applied for municipal solid waste (MSW) treatment; they are usually classified in view of the gasifying agent, reactor design, heat supply, pressure, temperature and form of solid residue [1]. However, majority of gasification-based plants, e.g., listed in [2], use air, not steam, as a gasifying agent, presumably due to negative energy balance of the process and specific technical problems of the such units. On the other hand, there were reported pilot, demonstration or industrial pyrolysis plants using indirect heating, some of them combining pyrolysis, gasification and melting operations [3]. Combination of two processes, i.e., thermolysis (pyrolysis) and steam gasification, was suggested in 1998 as a method of upgrading of the waste-derived solid fuel [4]. Based on laboratory experiments, authors of the paper demonstrated that the process enables trapping of some heavy metals by admixture of the kaolinite to gasified material and recovery of the gas composed mainly of H_2 (more than 50 vol.%) and carbon oxides CO/CO_2. At the same time, there was a paper published presenting in detail the possible development of RDF (refuse derived fuel) gasification with the O_2/steam mixture in the circulating bed gasifier, developed up to the industrial scale [5]. However, some years later, in 2004, T. Malkow wrote in an extensive paper [6] that "pyrolysis and gasification stand-alone applications … are in Europe still in a premature stage and expected not to play a major role in the near future" (T. Malkow presented in the same paper a large diversity of these technologies—investigated, tested or in use). A classical approach to the steam gasification of MSW has been presented in a set of papers of Chinese authors that were started in 2009. The series was opened with discussion of results of gasifying experiments performed in the laboratory-scale in the two-stage fixed bed reactor with samples of original MSW and natural dolomite as catalyst for cracking of tars [7][8]. Similar experiments were also performed in modified reactors for the evaluation of the catalyst, temperature, steam-to-MSW ratio and space velocity effect on the produced gas volume and composition [9][10][11][12][13]. Moreover, there are also papers comparing gasification of MSW with gasification of tires, poplar, RDF [14] or rubber, plastic and wood waste [15]. It seems that interest in steam gasification of MSW gradually increases now, and there are new papers being presented with a more general insight into the process, e.g., into a route for energy recovery [16], analysis of the process performance [17] or exergy [18]. This last one was based on the results of experiments in a semi-industrial fluidized bed gasifier, or conversion of MSW to SNG (Synthetic Natural Gas) [19]. Generally, researchers' attention was paid especially (but not only) to the gas quality, e.g., the syngas for methanol synthesis [2] or concentration of hydrogen [9][10][12][20][21][22]. It should be noted that thermodynamic modeling and simulation plays an important role in the analysis and technological assessments of gasification processing of waste, as was presented in papers on the syngas production from MSW in a bubbling fluidized bed [23], on the mathematical modeling of the MSW gasifier [24], in the CFD model (Computational Fluid Dynamics) of syngas production in a semi-industrial MSW gasification facility [25] and related CFD modeling of hydrogen production from MSW in comparison to biomass [26]. Usefulness of different forms of gasification for agro-waste should also be mentioned [27][28][29][30].

The Aim of the Investigation—Replacement of Incineration by Steam Gasification

Incineration, including MSW incineration, is a widely used process used for transformation, with energy recovery, of waste into mineralized material (ash). The process is performed in a reactor of a relatively small volume (on grates, in fluidized beds); however, it is followed by a complex sequence of physical and chemical treatments before emission of the flue gas to the atmosphere. Incineration requires the use of a large volume of air, which is transformed into an equivalent stream of flue gases. Chemical energy of the waste is converted to heat, but the gaseous stream is a "trade-mark" of incineration and determines the facility layout. The use of steam in excess definitely changes the process. Now the steam is the oxidation reagent for hydrocarbons from the pyrolytic step of the waste transformation, as well as for the carbonaceous residue from the pyrolysis itself. The gaseous stream at high temperature is a mixture of non-reacted steam and other reaction gases (mainly of hydrogen and carbon oxide). Condensation of steam during cooling is an efficient way of gas cleaning, from both inorganic contaminants as well as non-converted tars and oils. The condensate with contaminants should be returned to the reactor, closing the loop of reagents. As a consequence, allothermal steam gasification of the wastes enables elimination of the direct use of atmospheric oxygen (air) in the incineration/mineralization processes. We have demonstrated it in our earlier papers on the processing of electronic wastes [31][32][33].

We believe that the replacement of incineration by steam gasification transforms this traditional method of waste elimination in the “atmospheric open” flow reactor into a more advanced process of chemical refining of the waste to mineral/metal solid residue and producer gas (syngas). In the course of the experiments presented below, we gasified the residual from mechanical treatment of the municipal solid waste (RMT-MSW), which is an equivalent of the RDF-type material. We present the temperature dependence of the gas evolution intensity, quality of the recirculated condensate and thermodynamic assessment of the process enthalpy. However, in order to gain a more comprehensive picture of the waste transformation, it is necessary to take into account the properties of ashes (the solid residue) from gasification. We tried to present them in a separate paper [34] by giving details of acidic leachability of metals and comparing it with leachability from the ash prepared by incineration with oxygen. Furthermore, we recently discussed thermochemical cycles for some wastes, demonstrating equivalency of the initial and final states of both incineration and steam gasification [35].

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