Energy recovery from pyrolysis using non-recycled plastic

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Keywords: plastic waste, pyrolysis, thermal analysis.
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Introduction

Today, our society faces a twofold problem: the depletion of resources and the accumulation of waste. Plastics amounts a large part of the waste stream, which is currently not utilized or managed correctly, especially in the context of the circular economy. According to the hierarchy for the management of plastics and other waste places the prevention, reduction or reuse ahead of recycling, but sees the energy recovery as the least desirable option but ahead of landfilling. Plastic Waste is also a major source of water pollution that causes serious environmental problems. This kind of waste is a source of harmful micro-plastic fibers when left on land, in water bodies, or in the litter. In today's perspective, most of the waste plastic is landfilled or incinerated, but this does not address the challenge of energy sustainability. As an example, waste plastic can consist of different polymers, which are exposed to mechanical stress, oxygen, saltwater, ultraviolet radiation, etc. Moreover, their polymeric chains decompose and are eroded releasing various chemical species. Due to these reasons, they must be properly disposed of. This research will address issues such as non-recycled plastic recovery from pyrolysis due to decrease environmental pollution. Moreover, there will analyze the decomposition process of substances and characterize the produced chemical compounds by using thermal analysis (TG) and evolved gas analysis (FTIR). This study proposes an innovative waste recycling technique enabling to reduce the volume of waste dumped into landfills.

Experimental

Materials and methods

The pyrolysis of the waste was performed in the experimental pyrolysis reactor (Fig. 1) to determine the gas composition and conditions for char production. The experiments were performed at 550 °C and 850 °C temperature. A tube was filled with the plastic waste, then it was inserted into the furnace and heated to the desired temperature. The nitrogen gas flow rate (30 l/min) controlled by a flow meter (1) was fed to the top of the furnace, which was used as an inert atmosphere.

Thermal analysis of char from waste plastic was performed on a NETZSCH STA 449 F3 Jupiter analyser with a SiC furnace. In this study, the sample amounts of 10 mg were placed in the Al_2O_3 crucible in the TGA chamber along with a reference crucible, and the sample was heated in 10°C/min ramp steps up to 900 °C. The nitrogen gas flow rate of 30 ml/min was used as an inert atmosphere.

The taken gas samples were analysed using the Agilent 7890A gas chromatograph with a two-channel thermal conductivity detectors (TCD) and a set of valves: the first channel was used for separation of O_2, N_2, CO_2, CH_4, CO and light hydrocarbons, and the second channel, in parallel, for separation of hydrogen. Gas composition is determined conform the ISO 6974-4:2000 standard.

Results and discussion

Char production from waste plastics in pyrolysis reactor

Plastics from the separate collections or from commercial or industrial wastes often consist of clean mono-fractions, or of mixtures containing two to four polymers and only low levels of contaminants. It is known that the pyrolysis is the thermal destruction of plastics in an inert environment. Usually, three fractions are formed during pyrolysis: gases (H_2, CH_4, monomers); volatile liquids (aromatic hydrocarbons, paraffins) and carbon (C). In order to determine the pyrolysis conditions, the experiments were carried out in the pyrolysis reactor (see Fig. 1).

Thermal analysis

Two type of pyrolysis experiments of plastic waste at temperatures of 550 and 850 °C were performed. The sample was kept for 1 h after the pyrolysis reactor reached the desired temperature. Obtained char from waste was analysed on thermogravimetry NETZSCH STA 449.

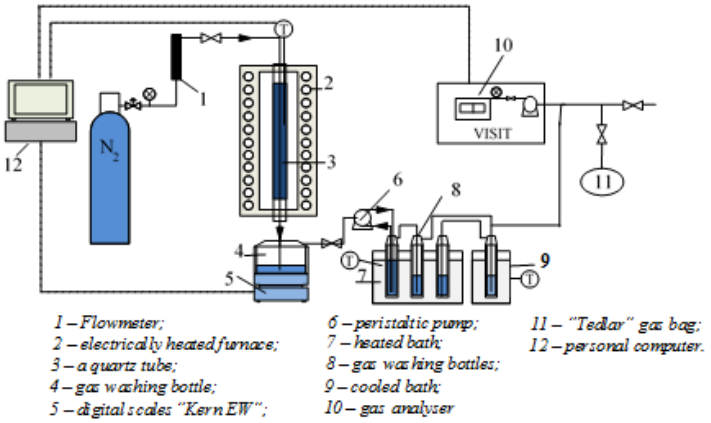

Fig. 1. Scheme of experimental rig for waste pyrolysis

The results of obtained char were compared with the base material (pure plastic). The amount of produced char was 10% at 550 °C, and at a higher temperature (850 °C) the amount of char was only 2% of the initial mass.

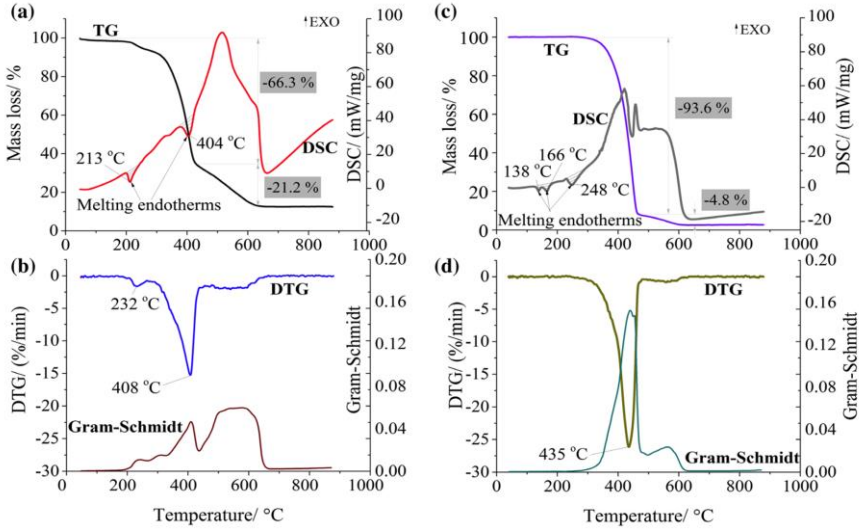

Fig . 2. Thermogravimetric analysis of contaminated and pure plastic

Determination of gas composition

The obtained gas samples at 550 °C and 850 °C were analyzed on the Agilent7890A gas chromatograph, which was used to identify the chemical composition of polymers waste. The results showed that the gas release from the plastic waste starts at ~220 °C temperature. The volatile CO and CO_2 gases are released first. The Gram-Schmidt diagram confirms that the largest amounts of gas were evolved at temperatures between 400°C and 600°C.

Conclusions

The objective of this study was to characterize the thermal processes and analyse the chemical compounds that are formed during pyrolysis. Gas chromatography (GS) and infrared spectroscopy (FTIR) used in this work have been proved as valuable techniques for analysis and identification of organic compounds. The technique of TG-FTIR-GC allows the direct analysis of small sample amounts without the need for time-consuming sample preparation. Based on the obtained results, the following conclusions can be drawn: a higher amount of char is produced at 550 °C pyrolysis temperature and obtained char can be utilized as an additive in the composite; the plastics thermal processing is an important application for both energy recovery and feedstock recycling.

References

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