MOTROL, 2007, 9, 178–183

APPLICATION OF THERMAL METHODS FOR UTILIZATION OF USED TIRES

Jarosław Szuszkiewicz

Faculty of Technical Sciences, University of Warmia and Mazury in Olsztyn

Summary The paper presents an experiment, whose purpose was to investigate the disposal of the polymer waste by plasma pyrolysis, on the example of powder from car tires. The plasma pyrolysis has some advantages over the conventional thermal methods in the processes of dissociation of difficult wastes. It is a promising technique for waste disposal of a variety of materials. The obtained results showed that the plasma pyrolysis was capable of disposing the rubber powder in over 90%.

Key words: plasma pyrolysis, thermal methods, utilization, tyres

INTRODUCTION

Disposal and utilisation of wide range of all kinds of polymers has become one of the most important issues of the present. This problem especially concerns environmental protection [Szuszkiewicz and Mizeraczyk 1995]. There have been worked out numerous methods and technologies dealing with polymer wastes, including rubber. The methods are characterized by different energetic and economic efficiencies. Generally, the disposal and utilisation methods have not been satisfactory so far and usually cause new problems connected with production of other hazardous and toxic compounds.

The plasma pyrolysis is a promising technique for waste disposal of a variety of materials [Szuszkiewicz and Mizeraczyk 1995]. This is a thermal treatment in the absence of any undesired reactants, only in the presence of inert gas (e.g. Ar) with admixture of desirable substances, like hydrogen or water vapour. The plasma pyrolysis has some advantages [Williams 1990] over the conventional thermal methods in the processes of dissociation of difficult wastes:

– operating temperature can be very high (up to 30000 K) [Coufal *et al.* 1994],

– heat generation is independent of the dissociation chemistry, whereby the operating temperature can be controlled,

– the waste treatment occurs in the controllable atmosphere,

– by using appropriate operating gas and thermal processing parameters the most suitable pyrolysis method ('pure' pyrolysis, pyrolysis with oxidation, pyrolysis with hydrogen reaction, pyrolysis with water reaction and pyrolysis with metal reaction) can be chosen.

Although several experiments have been carried out the plasma pyrolysis processing of polymer waste is still far from satisfactory in both the economic and environmental aspect.

The paper presents an experiment, whose purpose was to investigate the disposal of the polymer waste by plasma pyrolysis, on the example of powder from car tires. For this purpose a plasmatron with an electrical power of max. 40 kW was used. Argon or mixture of argon with hydrogen was an operating gas. The plasma pyrolysis was carried out in an air-proof reactor to prevent the ambient air from influencing the process. Similar experiments on plasma pyrolysis of rubber powder were carried out by Chang *et al.* [1993, 1996, 2003].

EXPERIMENTAL

The scheme shows the experimental set-up (Fig. 1). The main parts of the set-up are: a plasmatron, DC power supply, cooling systems, rubber powder feeder, control units and gas supply. In the experiment a DC plasmatron with indirect arc, of a maximal input power of 40 kW, was used. The arc discharge was induced in the operating gas stream (Ar or Ar with H_2) between two electrodes: the tungsten cathode and copper anode. As a result a plasma jet suitable for thermal pyrolysis was produced. The electrodes were cooled with water to reduce the heat and to improve power density and stability of the jet. For the purpose of this experiment the anode nozzle, where the plasma jet is formed and shaped, was lengthened. As a result the rubber powder remained longer within the plasma jet. The rubber waste was powdered and transported to the reactor using a powder feeder. The powder was injected into the plasma torch within the anode, perpendicularly to its axis.

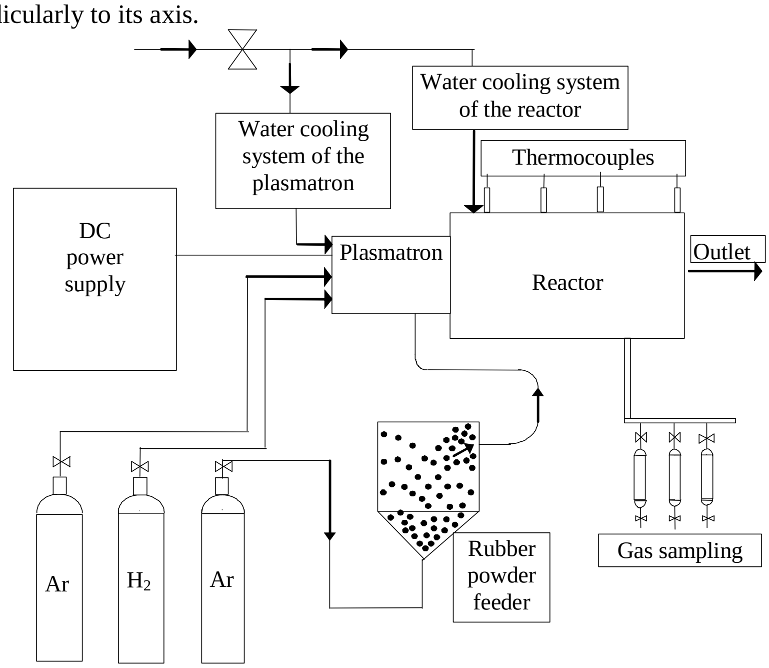

Fig. 1. Experimental set-up for pyrolysis of rubber waste

The plasma jet developed in a closed reactor (Fig. 2), which prevented the air from accessing the volume where pyrolysis takes place. A water jacket lowered the temperature inside the reactor and protected the inner walls of the reactor from overheating. Low temperature of the gas in the reactor prevented pyrolyzates from synthesising new undesired chemical compounds.

The gas for the analysis was sampled through a pipe probe placed inside the reactor. The collected samples were analysed by the Fourier Transform Infrared (FTIR) absorption spectroscopy with a FTIR- Elmer Perkin unit.

It was found that maximum 8.05 kg of the rubber powder per hour could be delivered into the plasma jet without suppressing it.

The discharge current varied from 350 A to 550 A. At high percentage of H_2 in the ($Ar + H_2$) plasma gas a flame appeared at the outlet of the reactor. It might have been caused by either flammable products of the pyrolysis or H_2 from the plasma gas, which burned in the ambient air after leaving the reactor.

RESULTS

Black solid ash, containing soot, was found inside the reactor, also on its inner walls. The Atomic Absorption Spectrofotometry, Flame Fotometry and KBr tablet methods showed the ash contained several metals including Zn, Ca, Na and compounds with SO_2 group (Chang et al [1993, 1996] found 3.5 % of sulphur in the ash).

In the absorption spectra of the flue gas the infrared bands of CH_4, C_2H_2, CO, CO_2 and unidentified compounds, probably hydrocarbons (called 'alfa' for the purpose of the experiment) were found (Fig. 3). No harmful NO_x and SO_2 were detected in the flue gas by our FTIR unit (detection limit of several ppm).

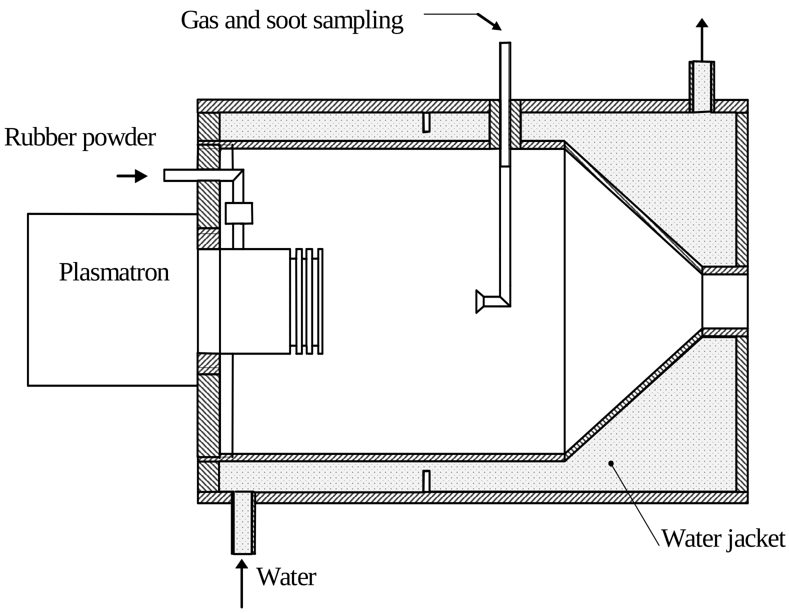

Fig. 2. Scheme of reactor with plasma generator

Ar plasma without rubber

A test experiment was carried out with no rubber powder delivered to the Ar plasma jet. No molecular bands were found in the recorded FTIR spectrum.

Pyrolysis of rubber powder in ar plasma

In all the tested outcoming gas samples the main gaseous products of the pyrolysis were: CH_4, C_2H_2, CO and CO_2. Their production increases with increasing plasmatron electric power. Only C_2H_2 production increased monotonically with increasing rubber powder mass flow rate.

Pyrolysis of rubber powder in ($Ar+H_2$) plasma

CH_4, C_2H_2, unknown ‘alfa 1’ and ‘alfa 2’ compounds, CO and CO_2 were identified in the absorption spectra (in a similar experiment Chang *et al*. [1993, 1996, 2003] found also C_2H_4 and NH_3).

Like in the case of Ar plasma pyrolysis, the production of CH_4, C_2H_2, ‘alfa’ compounds, CO and CO_2 increased with increasing input power.

The production of C_2H_2 and also ‘alfa’ compounds increases monotonically while increasing rubber powder mass flow rate. The production of CH_4, CO and CO_2 is not monotonic.

The production of CH_4, ‘alfa’ compounds, CO and CO_2 increases while increasing H_2 percentage in the plasma gas (Fig. 4); only the concentration of C_2H_2 is not monotonic.

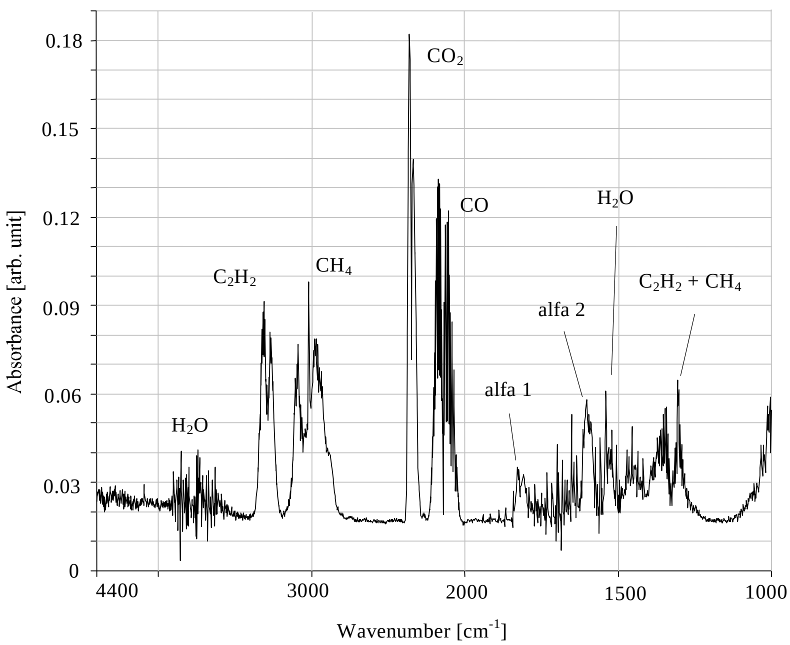

Fig. 3. An example of the absorption spectrum of outcoming gas for the case of ($Ar + 5.9\%\ H_2$) plasma gas (Operating voltage – 52 V, discharge current – 500 A, gas flow rate – 5538 l/h)

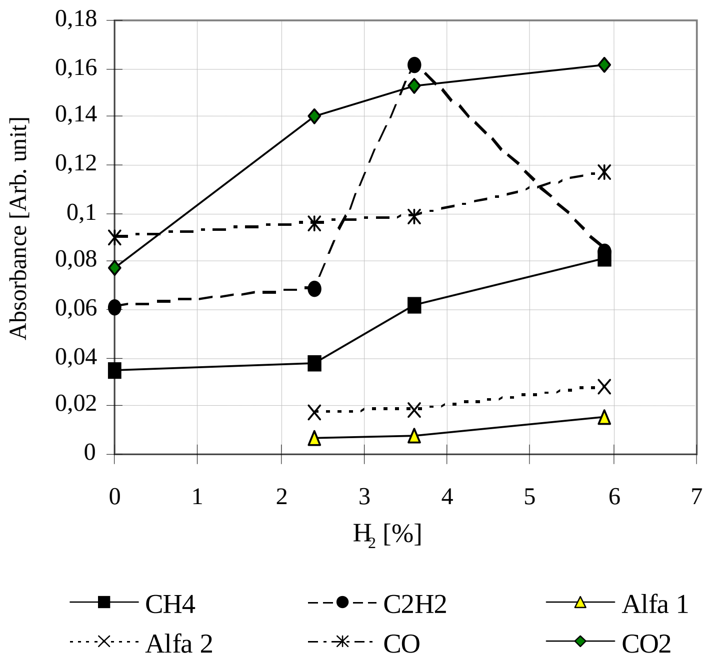

Fig. 4. Influence of H_2 percentage in the plasma gas on production of CH_4, C_2H_2, CO, 'alfa 2' compounds and CO_2 in the plasma pyrolysis of rubber powder

CONCLUSIONS

The obtained results showed that:

1. The plasma pyrolysis was capable of disposing the rubber powder in over 90%.
2. there are differences between plasma pyrolysis in the Ar plasma and (Ar + H_2) plasmas.
3. CH_4, C_2H_2, unidentified hydrocarbons ('alfa' compounds), CO and CO_2 were found as products of the plasma pyrolysis of the rubber powder.
4. No SO_2, NO_x or hydrogen cyanide (HCN) were identified in the flue gas.
5. In the Ar plasma, increasing of the input power results in the production increase of C_2H_2, CH_4, CO and CO_2 in the flue gas. No production of 'alfa' compounds was observed. Increasing of the rubber powder mass flow rate monotonically increases the production of C_2H_2.
6. In the (Ar + H_2) plasma, plasma jet electrical power increases with increasing H_2 percentage. The increase of the input power increases the production of all the identified compounds. If H_2 percentage in the (Ar + H_2) plasma gas increases the concentrations of CH_4, CO, CO_2 and 'alfa' compound increase; concentration of C_2H_2 is not monotonic. If the rubber powder mass flow rate increases the concentration of C_2H_2, and 'alfa' compound monotonically increase; concentration of CH_4, CO and CO_2 is not monotonic. The presence of H_2 in the plasma gas is essential for CH_4 and C_2H_2 production.

The carried out experiments showed that plasma pyrolysis is a promising technology for polymer waste recycling.

REFERENCES

Chang J.S., Gu B.W., Chu F.Y., Simpson C.J. 1993: EP- 93−72, 21−30.

Chang J.S., Gu B.W., Looy P.C., Chu F.Y., Simpson C.J. 1996: Environ. Sci. Health, A31(7), 1781−1799.

Chang J.S., Takamura Y., Jamal S., Ono S., Teii S., 2003: EP-96-28, 51−59.

Coufal O., Gregor J., Šenk J. 1994: Proc. 1st Int. Conf. on Electromagnetic Devices and Environmental Protection ELMECO'94, 93−97.

Szuszkiewicz J., Mizeraczyk J. 1995: Zeszyty Naukowe ART w Olsztynie, Zeszyt Mechanika, 91−104.

Williams P.T., 1990: Fuel, 69, 1474−1482.