

## APPARATUS FOR PLASTIC WASTES UTILIZATION

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**A b s t r a c t.** The aim of the researches was to study the utilization of plastic wastes such as PE, PP, PS, used car tires and compositions of bitumens modified by polymers by new method, which is combined of thermal pyrolysis and non-equilibrium plasma. These plastics wastes were heated from the room temperature to the temperature of 1000°C in pyrolysis furnace and the volatile products of pyrolysis were combusted at oxygen atmosphere in plasma chamber, where plasma was generated by gliding discharge. The efficiency of combustion of the main gaseous species of pyrolysis were 99.9%.

**K e y w o r d s:** gliding discharge, pyrolysis, polyethylene, polypropylene, polystyrene, bitumen, car tires.

### INTRODUCTION

The ceaseless increase of using plastics in many different fields of economy and industry causes the increase of the plastics wastes amount which are derived from packaging and production processes. Plastics are part of about 7-8% of the solid wastes mass. Most of the plastic wastes, about 77%, are polyolefines like polyethylene or polypropylene and the rest are 12% of polystyrene, about 5% of polyvinyl chloride and about 6% of the others. In 1997 the total consumption of plastic was 27,281,000 tons in the European Community. More than 10 million tons were polyethylene (PE) and nearly 6 million tons were polypropylene (PP). Polyvinyl chloride (PVC) and polystyrene (PS) followed with a consumption of 4.6 million or 2.7 million tons respectively. Forty-two per cent of all plastics were used for packaging [1]. The other large group of solid wastes is the group of used car tires and wastes of the compositions of bitumens modified by polymers, which were used in foundry industry or after briquetting, as binders of, for example, fine coal or wood sawdust for cooking [2]. There is a need and important problem of finding safe method of utilization these kinds of wastes.

Finding cost-effective economic, energy and technological process has been the main study for utilization of plastic wastes. One of the methods to utilization of

plastic wastes was the process for co-liquefying coal and plastic wastes [3]. Preliminary design was developed for two processes configurations for utilization of plastic wastes. First process configuration concerns generated from coal gasification hydrogen and second process configuration concerns hydrogen which is generated from cellulosic-waste gasification.

The other method of plastic wastes utilization is co-gasification process. This process was applied to conversion of mixture plastic and biomass wastes into synthesis gas (CO and H<sub>2</sub>) [4]. Mixtures of plastics and wood pine as a biomass waste are used, varying the plastic content in the range from 20 to 60%. The process working conditions vary in the following range: reaction temperature – 730-900°C. Finally, the gasification reactions of the remaining carbonaceous residue occur with steam and carbon dioxide.

The next possible method of plastics waste utilization is thermal or catalytic cracking [5]. As a result of the cracking at 400°C or higher process temperature some quantities of hydrocarbon mixtures in the form of gas, liquid products (gasoline and diesel fuel boiling range) as well as higher boiling liquid residue or solid can be obtained. Waste samples of plastics, for example polyethylene and polystyrene, are cracked thermally or in the presence of catalyst and hydrogen. Cracking or hydrocracking of polyethylene connected with hydrogenation step gives mainly paraffin fractions while in the case of polystyrene highly aromatic fraction fuel fractions. These processes are continuous processes and they are possible to use at large scale.

The object of the present researches was to study the possible utilization method of plastic wastes such as PE, PP, PS, bitumen-polymers composition (DHR/EPS) and used car tires wastes by new method, which combined thermal pyrolysis of wastes with combustion of volatile product of pyrolysis using gliding discharge.

Pyrolysis was used for thermal conversion of plastic wastes from solid into gas phase. The solid wastes were heated from the room temperature to the temperature of 500-1000°C in pyrolysis furnace and the volatile products of pyrolysis were combusted in gliding discharge.

Non-equilibrium plasma, which was used in our study, was generated by gliding discharge. The plasma, which was generated by gliding discharge, contained electrons, ions, radicals and other excited species. In this plasma the electrons are average energy from 1 to 10 eV while the energy of ionic and neutral species is about 10 times lower and correspond to the temperature of 500-1000K. The gliding discharge has been applied for flue gas treatment and has been used with positive results for decomposition of pollutants [6,7] and chemical synthesis [8], because the chemical compounds are decomposed to atoms or ions in plasma.

## EXPERIMENTAL

### Apparatus

The plastic wastes utilization process was carried out in the same apparatus described in early study [9]. Schema of the apparatus is showed in Fig. 1. The apparatus contains the pyrolysis furnace, which is electrically heated. This furnace is connected with a plasma chamber. The water cooler is located next to the plasma chamber.

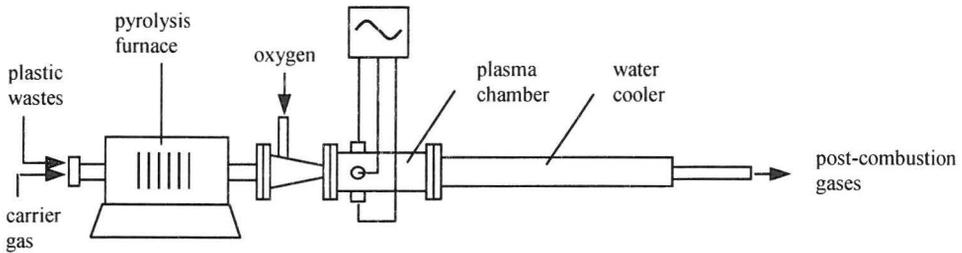


Fig. 1. Schema of the plastic wastes utilization apparatus.

### Plasma chamber

Three stainless steel electrodes are placed in the plasma chamber. Schema of electrodes configuration in plasma chamber is showed in Fig.2. The gliding discharge is fed by a special 3-phase high voltage 50Hz power system. The averaged electric power, which was fed into the reactor, was measured using classical 3-phase energy meter.

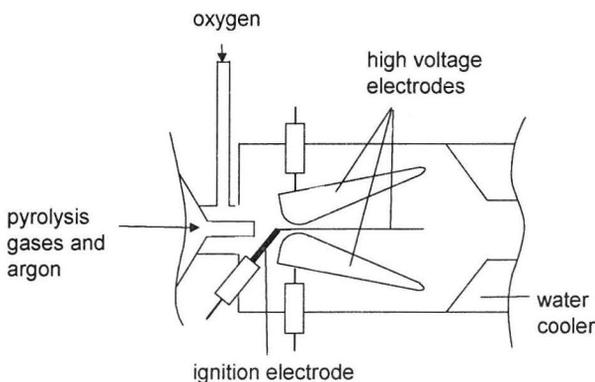


Fig. 2. Schema of electrodes configuration in plasma chamber.

### Characteristic of the wastes

Process of utilization of five different plastics was investigated in this work:

1. polyethylene (PE),
2. polypropylene (PP),
3. polystyrene (PS),
4. bitumen polymer composition, which contained 90% of dark hydrocarbon resin (DHR) and additive of 10% of foamed polystyrene (EPS),
5. car tires with the most popular tire size 165-R13.

Thermal decomposition (pyrolysis) of PE, PP and PS under argon atmosphere condition is showed in Fig. 3. The Result of the thermal degradation of PE, PP and PS demonstrate that the plastics almost completely transform from solid into gas phase below 500°C, only less that 0.1% of the beginning mass was remained. It is obvious that the order of thermal stability of the studied plastics is PE>PP>PS. The mechanism of thermal degradation of the plastics was identified as a radical chain mechanism and the kinetics model was described [10, 11]. These authors reported that the main product of plastics pyrolysis were monomers.

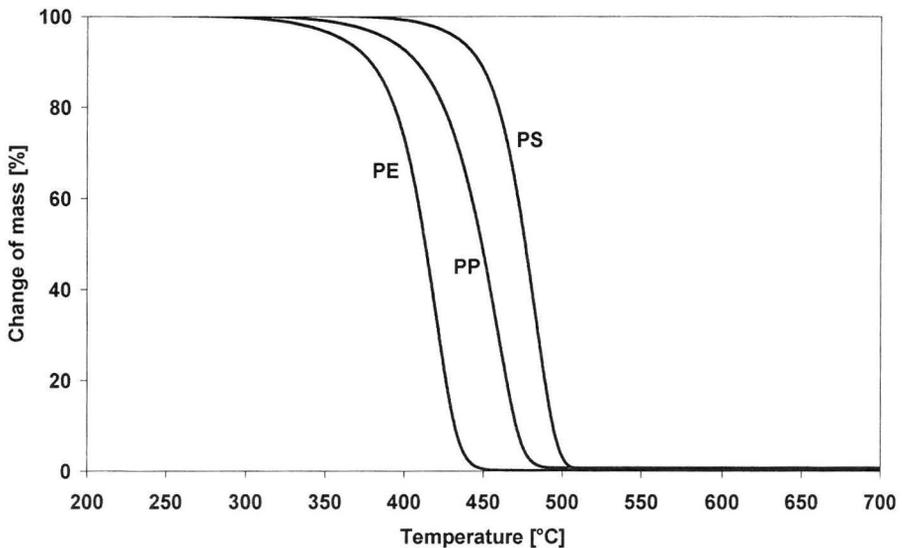


Fig. 3. TG curves of single plastics recorded under argon at a heating rate of 10°C/min.

Tires and DHR/EPS wastes can not transformed completely into gaseous form because they are contain filling material such as carbon black in large quantity.

### Experimental conditions

The apparatus was projected to work as batch process. First step was loading the plastics waste into the furnace and then closing the furnace. Argon, as a carrier gas, was let through the furnace. The furnace was heated from the room temperature to the temperature of 500-1000°C; solid wastes were converted into gaseous form at this temperature. The post-pyrolysis gas consists methane, ethane, ethylene, acetylene, propylene and other volatile hydrocarbons. Next, the mixture of argon and volatile hydrocarbons was injected into the plasma chamber. In this chamber the gases from the furnace were mixed with oxygen and the hydrocarbons were combusted. Oxygen was injected into the plasma chamber separately. The post-combustion gases were cooled in a water cooler. Parameters of the experiments are showed in Table 1.

**Table 1.** Experimental parameters.

Material	PE	PP	PS	DHR/E PR	DHR/E PR	Car tires
Temperature of pyrolysis, °C	500	500	500	600	1000	1000
Argon flow rate, L (S.T.P.)/h	600	600	600	750	750	750
Oxygen flow rate, L (S.T.P.)/h	1200	1200	1200	750	750	750
Discharge power, kW	2.4	2.6	2.7	2.0	2.1	2.1

### Analysis

The plastic wastes were weighted before loading into the furnace. The solid residues, which was remained in the furnace after pyrolysis, were weighted too.

The quantitative and qualitative analysis of post-combustion gases were determined using chromatographic method.

## RESULTS AND DISCUSSION

Solid residues, which remained after pyrolysis of tires and DHR/EPS wastes at 1000°C, were respectively 35% and 24% of beginning mass (Table 2).

**Table 2.** Results of utilization car tires and DHR/EPS.

Material	DHR/EPS	DHR/EPS	Car tires
Temperature of pyrolysis, °C	600	1000	1000
Solid residues, % by mass	43	24	35

The concentration of pollutants in the post-combustion gases were presented in Table 3. The post-combustion gases were pure, usually concentration of all hydrocarbons in post-combustion gases was less than 100 ppm. The high yield of the post-combustion gases was achieved because the flow of gases were disturbed by the narrows between plasma chamber and water cooler, which provoked a phenomenon of re-circulation of the reactant in plasma zone. Because of this special construction the plasma chamber could work with the high efficiency, see Table 4. The values of the efficiency of combustion of the main species, which are consisted in the pyrolysis gases, were high, about 99.9%.

**Table 3.** Concentration of hydrocarbons in the post-combustion gases.

Material	PE	PP	PS	DHR/EPS, 600°C	DHR/EPS, 1000°C	Car tires
Methane (ppm)	20	<10	<10	15	15	30
C-2 fraction (ppm)	75	<10	30	<10	<10	<10
C-3 fraction (ppm)	<10	<10	<10	-	-	25
Styrene (ppm)	-	-	360	-	-	-

**Table 4.** Efficiency of combustion of PE pyrolysis gases.

Pollutant	Concentration before combustion (ppm)	Concentration after combustion (ppm)	Efficiency of combustion (%)
Methane	5000	20	99.6
Acetylene	8000	<10	99.9
Ethylene	5800	65	99.9
Ethane	280	<10	96.4
C-3 fraction	700	<10	98.6

The results, which were obtained using presented method, are showed that it is effective way to utilization of plastic wastes.

## CONCLUSIONS

The results of the investigation showed that:

1. The results of the utilization of plastic wastes, which were obtained using presented method, were fully satisfactory.
2. PE, PP and PS were decomposed completely to volatile hydrocarbons below 500°C.
3. The mass of DHR/EPS composition waste was reduced to 24% of beginning mass at 1000°C.
4. The mass of the used car tires wastes was reduced to 35% of beginning mass at 1000°C.
5. Usually the post-combustion gases were pure with concentration of all hydrocarbons below 100 ppm.
6. The combustion efficiency of the main volatile species of pyrolysis was 99.9%.

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## APARATURA DO UTYLIZACJI TWORZYW SZTUCZNYCH

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**S t r e s z c z e n i e.** W przedstawionej pracy zaprezentowano efekty utylizacji odpadów z tworzyw sztucznych ( z PE, PP, PS, zużyte opony) z wykorzystaniem nowej metody pirolityczno-plazmowej. Tworzywa podgrzewano do temperatury 1000°C w piecu do pirolizy, a lotne produkty były spalane w atmosferze tlenu w komorze plazmowej wyladowania ślizgowego. Efektywność spalania podstawowych produktów gazowych wynosiła 99.9%.

**S ł o w a k l u c z o w e :** wyladowanie ślizgowe, piroliza, polietylen, polipropylen, polistyren, bitumy.