Plasma-thermal processing of rubber crumb from waste tires

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Abstract: These results are for the investigation of crumb rubber processing from waste tires by a plasma-thermal methods presented. The plasma system is based on using an induction plasma torch at a frequency of 2 MHz, up to 50 kW and a low-frequency induction heating module at a frequency of 20-40 kHz and load power up to 15 kW.

Keywords: RF plasma, induction, carbon, syngas, tire reclaim processing

1. Introduction

According to the European Association for the recycling of tires (ETPA) scrap tires in Europe are about 2 million tons per year and only 10% are recycled mostly by grinding. Some of the collected tires (20%) are used as fuel. Used tires are a source of long-term pollution. Waste tires are not only a valuable secondary raw material containing 65-70% rubber, 15-25% carbon, 10-15% of the metal, but also is a valuable source of renewable energy.

Some technologies and techniques for waste tires; such as separation of metal cord and crumbling rubber; are well developed. The research and studies aimed to increase the complexity of the use of crumb rubber by generating synthesis gas and carbon black are still not completed, but technically implementable. This paper presents the results of studies on plasma-thermal processing of waste produced in the disposal of waste tires.

2. Experimental Set Up

Investigations were carried out on a plasma system based on a modular design. This approach gave us the anticipated flexibility and allowed us to develop unique plasma units with a maximum efficiency specifically to this chemical / technology process. The process is based on radio frequency (RF) induction plasma torch (Fig. 1). As a power supply, we used a LEPEL RF generator with variable power from 0 to 100 kW at 2 MHz frequency. The reactor was additionally heated by using low-frequency induction (NCHI) generators with a variable frequency from 20 to 40 kHz at 15 kW power. Modular construction of the installation allowed for various combinations of the technological equipment and supported a wide range of processing parameters. For example, the system could work with the plasma torch only or with induction heating only or both (Fig. 2).

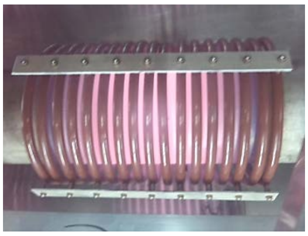
Plasma installation is developed based on block-modular design that gave us a technological flexibility: orientation of the reaction zone (reactor): vertical, horizontal or tilted at any angle. In addition, it is possible to carry out studies of combined, plasma – thermal

Fig. 1. Experimental installations.

processing method of crumb rubber (Fig. 2a). Or the thermal heating was carried out by only low-frequency induction generator (Fig. 2c). The temperature in the mixing zone, where the raw material is introduced into the plasma, can vary from 1 000 to 8 000 °C by changing the power from 1 kW to 75 kW. The preferred temperature is not lower than 1 200 °C because at lower temperatures carcinogenic dioxins could be generated. At the experimental stage, powdered rubber was fed through the discharge zone and into a plasma jet. The last option appeared preferable, since that discharge chamber was not contaminated by carbon. During the plasma treatment (interaction of the plasma with rubber crumb) carbon black and synthesis gas (mixture of hydrogen and carbon monoxide) are produced. Syngas calorific value is slightly lower than of natural gas, but the content of hydrogen and CO is optimal for a variety of applications. The temperature profile in the mixing zone was different for different regiments and depends on the following parameters: plasma power, raw material feed rate, chemical composition of plasma and carrier gases and flow. Analyses showed that at higher specific power (kW/kg) the synthesis gas is increased proportionally and the fraction of nanoscale carbon black is raised to 80%.

a)

b)



c)

Fig. 2. Different mode of powdered rubber processing: a) plasma-thermal, b) plasma only, and c) thermal.

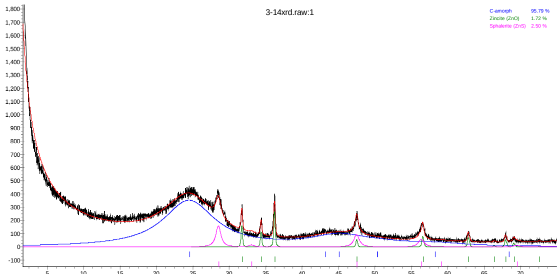
3. Result and Discussion

Some of the experimental data are shown in Table 1 and on Fig. 3 for samples (1-6) obtained under different regiments. The use of combinations of plasma and induction heating effect allows for flexible control of carbon black properties. For example, when the powder is exposed only to the plasma (samples 5-6), the metal impurities (leftover from waste tire powder preparation) are greatly reduced. Iodine number (Iodine Adsorption number) is 30 to 50 g/kg, which corresponds to international qualification grades of carbon black N 650, N 660, N 539, N 550. Therefore, it was possible to regulate the ratio H_2/CO by controlling the enthalpy and composition of the plasma. In addition, by varying the process parameters, we obtained no liquid fraction (synthetic oil) in the final products. The absence of liquid phase dramatically simplifies the technological process, because it is not necessary to design and use a unit for collecting the liquid fraction. The solids were collected in the product container, which is equipped with a line of filters. Preliminary experiments have shown the possibility of production of carbon black in nano size range (50 to 300 nm).

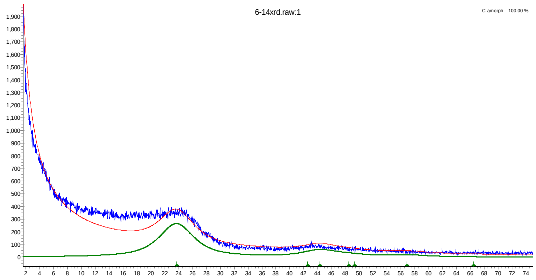
Currently, the Joint Stock Company "Volga-Kama Joint rubber and appliances /" QUART "/, is testing the plasma produced carbon black as an additive to different rubber products. Carbon black has been used successfully in the production of secondary composite rubber having high deformation strength properties; in the manufacture of noise-shielding material for highways, fences, parking lots, rubber coating for crossings over railway lines, etc.

Table 1. Chemical composition of carbon black. (method: X-ray fluorescence analysis; Instrument type: SUR–02 "Renom FV).

Element	Sample No.					
	1	2	3	4	5	6
Zn	4.5	1.4	4.5	4.3	0.3	0.7
Fe	0.3	1.4	0.4	0.3	0.3	0.3
Cu	0.06	0.2	0.07	0.05	0.02	0.02
Br	0.3	0.2	0.13	0.11	0.07	0.09
S	4.3	5.4	4.2	4.6	8.5	8.3
K	0.2	0.3	0.2	0.12	-	-
Ca	0.3	0.8	0.4	0.4	0.6	0.5
Cr	-	0.15	-	-	0.12	0.06



a)



b)

Fig. 3. X-ray analysis of carbon black: a) Thermal treatment only, and b) Plasma-thermal treatment.

4. Conclusion

The advantage of the plasma thermal method is the ability to adapt the equipment to the variable types of raw materials and obtain various desired physical and chemical properties of the product. Using the combination of plasma and induction heating for rubber powder processing allows for a greater fraction of the nano-dispersed carbon black, which will increase the performance of rubber products by using such carbon black as additives.

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