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CARBON BLACK MAKING BY GLIDING DISCHARGE

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A b s t r a c t. The aim of the work was to work out and develop the method and the apparatus for making carbon black from hydrocarbon gases, methane and acetylene, using gliding discharge. Under conditions of gliding discharges, non-equilibrium plasma is generated. Using this method it is possible to develop a new and safe process for carbon black manufacturing, which is an important raw material for plastics and rubber industries all over the world. That is why the efficient, economical, and environmental friendly process for carbon black manufacturing is the goal of many investigations.

K e y w o r d s: carbon black, gliding discharge, methane, acetylene.

INTRODUCTION

The increase of using and applications of plastics and rubber products in many branches of industry all over the world, like motorization and car tires production, creates the needs of finding new and safe methods of making carbon black. The increase of competition, mostly in rubber market, forces the carbon black industry to improve, modernization and development and that is why there is an urgent necessity of elaboration of a highly efficient, economical and environmentally friendly process and finding new technologies of carbon black production of the best quality and purity. Besides rubber industry, carbon black is used in plastics industry (as filler) and in production of paints, lacquers and inks.

Carbon black is generic name, which describes wide group of industrial carbon products with systematic nanostructures of elementary carbon [1, 2]. Conventional processes of carbon black making, in industrial scale, base on incomplete combustion of high-boiling aromatic oils or natural gas (furnace and channel processes). There is generally known that one of the cheapest and relatively readily available hydrocarbon gas is methane, which could be used in carbon black production process. Conversion of methane to carbon black in furnace process can give not more than 22 kg of the solid product from 1000 m^3 of the gas, but the stoichiometry of the reaction shows that total conversion of the same amount of methane to elementary carbon can give 500 kg of carbon black. In that process methane is used not only as raw material but also as fuel being the source of energy consumed in the processes. Conventional process of carbon black production is hard to exploit and it fails to comply with requirements of environmental friendly process, because of the emission to the atmosphere of CO, CO_2, NO_x, volatile hydrocarbons, carbon black and aromatic hydrocarbons seated on carbon black particles [3]. That is why there is an urgent need of developing a new process of carbon black manufacturing, including the plasma method.

Up till now, some investigations has been performed where a new process and apparatus are developed for hydrocarbon processing into carbon black by gliding discharge under non-equilibrium plasma conditions.

EXPERIMENTAL

Carbon black making by gliding discharge process described before [4] was carried out in the apparatus showed in Fig. 1. The plasma reactor consisted of three stainless steel special shape main electrodes and one ignition electrode. Three main electrodes are situated symmetrical around the ignition electrode at an angle of 120°. The reactor is connected to the water cooler and cyclone where all the post-reaction dust is precipitated from gas. Carbon black is accumulated in a tank, which is situated under the cyclone. Next to the cyclone, the filtering system is located for very precise gas cleaning from the dust. Cleaned gas is taken to the gas burettes for analysis. Using this apparatus, the process can be conducted in continuous mode.

After preliminary establish suitable flow rate and composition of gas reagent and carrier gas mixture, gas stream is injected into the reactor by a nozzle, which is situated above the electrodes. Positions of the main electrodes, the ignition electrode, and the nozzle may be changed so as to get the best efficiency of the process.

In our investigations, two gas reagents were used, methane and acetylene, in mixtures with argon as carrier gas. The process conditions are showed in Table 1.

The gliding discharge was fed by a special 3-phase 50 Hz high voltage power system. The averaged electric power of the reactor was measured using a 3-phase kWh meter. The composition of post-reaction gases was determined by using chromatography methods.

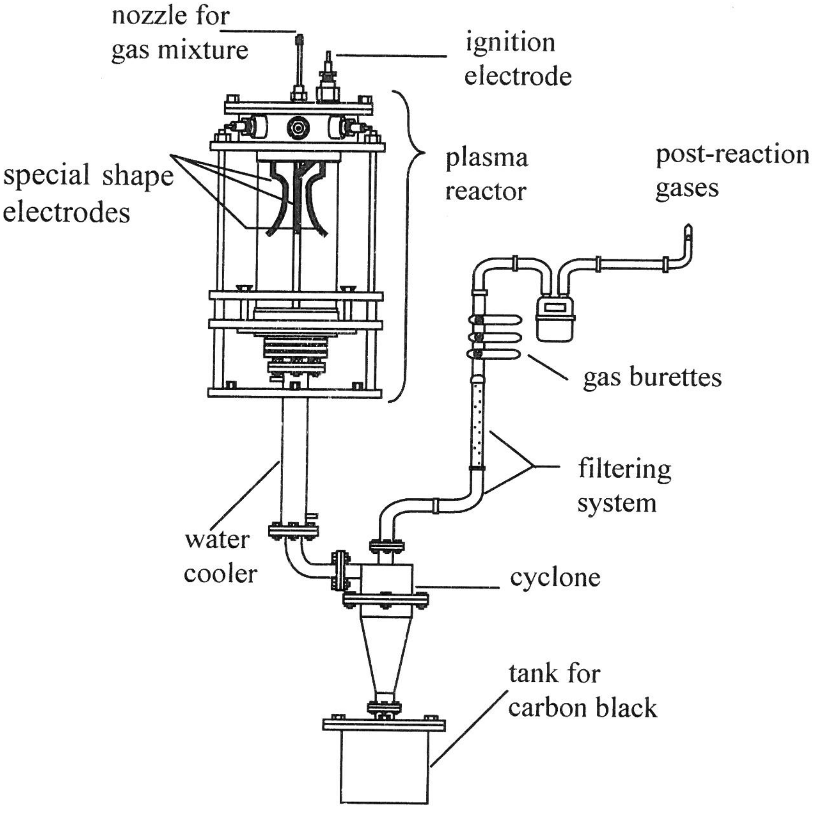

Fig. 1. Schema of carbon black making apparatus by gliding discharge.

Table 1. Process conditions and gas mixtures compositions in carbon black making process.

Gas composition [carrier gas and reagent mixture]	**Process conditions**		
	Flow rate [m^3/h]	***Content of reagent*** *in gas mixture* [% by vol.]	***Discharge power*** [kW]
Ar – CH_4	1.5	5-20	1.0-1.51
Ar – C_2H_2	0.5-1.25	5	0.7-0.96

RESULTS AND DISCUSSION

The conversion of reactant in the process and energy consumption depend on composition of starting gas mixture. For example, the total conversion of methane and the conversion of methane to carbon black grow up with increasing gas reagent content in the starting mixture. The conversion of methane versus Ar-CH_4 gas mixture composition, for the flow rate of 1.5 $m^3 h^{-1}$ is shown in Fig. 2.

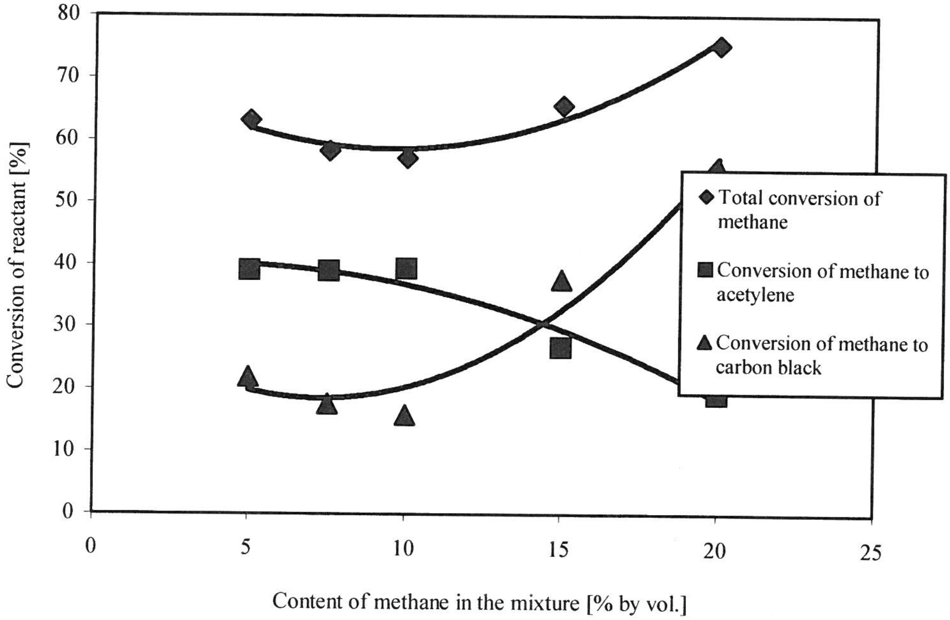

Fig. 2. Conversion of methane vs. content of methane in the starting gas mixture (total flow rate – 1.5 $m^3 h^{-1}$; carrier gas – Ar; reagent – CH_4)

The conversion of reactants for different gas compositions is showed on Table 2.

The energy consumption decreases with increasing methane content in the gas mixture. This relation for the flow rate of 1.5 $m^3 h^{-1}$ is shown in Fig. 3.

The conversion of reactant slightly depends on the value of the total flow rate of the gas mixture. Increasing of the flow rate causes the insignificant increasing of the conversion of reactant. Figure 4 shows this relation for Ar(95%)-C_2H_2(5%) gas mixture.

Table 2. Conversions of reactants in carbon black making process.

Gas composition [reagent and carrier gas mixture]	**Conversion of reagent**	
	Total conversion of Reagent [%]	*Conversion of reagent to carbon black* [%]
Ar – CH_4	31-75	16-55
Ar – C_2H_2	37-49	35-47

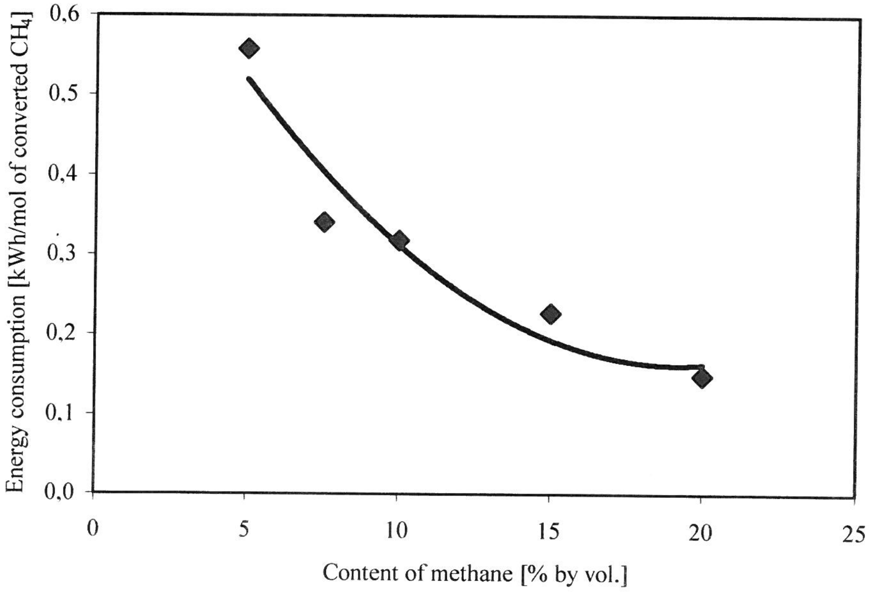

Fig. 3. Energy consumption of carbon making process depended on content of methane in the gas mixture (total flow rate – 1.5 $m^3 h^{-1}$; carrier gas – Ar; source gas – CH_4)

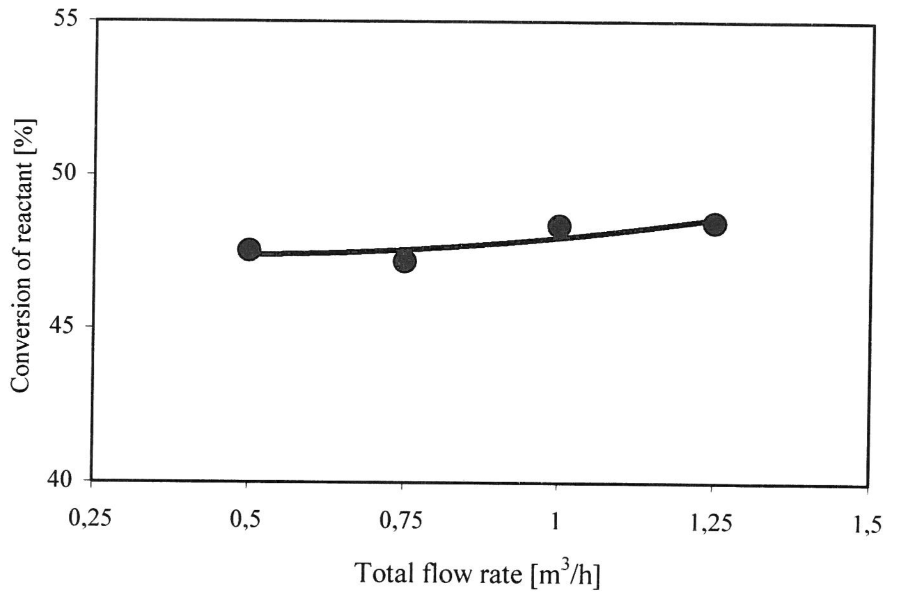

Fig. 4. Conversion of acetylene in carbon making process depended on flow rate of the gas mixture (concentration of C_2H_2 – 5 % by vol.; concentration of Ar – 95 % by vol.)

SUMMARY AND CONCLUSIONS

The object of these researches was to work out and develop the method and apparatus for making carbon black from selected hydrocarbon gases using gliding discharge. The received results of the investigations showed that:

1. The conversion of reactant grows with the increase of hydrocarbon content in the mixture with carrier gas. The conversion of methane is higher than this of acetylene:
   - The total conversion of methane grows to 75% and conversion of methane to carbon black grows to 60% with the increase of methane concentration in the gas mixture to 20% by vol.
   - The total conversion of acetylene grows to 49% and conversion of acetylene to carbon black grows to 47% with the increase of acetylene concentration in the gas mixture to 10% by vol.
2. The concentration of gas reagents influences the energy consumption, which decreases with the growing concentration of methane in the gas mixture.
3. The conversion of acetylene slightly increases with the increasing gas flow rate.

ACKNOWLEDGEMENT

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OTRZYMYWANIE SADZY TECHNICZNEJ W WYŁADOWANIU ŚLIZGOWYM

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S t r e s z c z e n i e. Celem pracy było opracowanie i rozwój metody i aparatury dla wytwarzania sadzy z węglowodorów gazowych, metanu i acetylenu, przy wykorzystaniu wyładowania ślizgowego. Rozwój tej metody pozwoli na bezpieczną i przyjazną dla środowiska produkcję sadzy, materiału wykorzystywanego w przemyśle gumowym i tworzyw sztucznych na całym świecie.

S ł o w a k l u c z o w e : sadza, wyładowania ślizgowe, metan, acetylen.