Power Consumption of Gliding Arc Discharge Plasma Reactor

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Abstract—Power consumption of the gliding arc discharge plasma rector and its stable operation depends on many factors, among which the most important are: power supply system configuration, processing gas flow rate and its chemical composition. Trace gases admixtures can essentially influence the plasma chemistry process. Argon admixture to the processing gas stabilizes the discharge and makes possible to transfer larger power from the power supply system to the discharge. Correctly selected power supply system decides about plasma chemistry and technological application of this kind of non-thermal plasma.

Keywords—Plasma, glidarc, power supply system

I. INTRODUCTION

Nowadays atmospheric pressure low temperature plasmas are applied in many industrial processes. They are: treatment of flue gases emitted by industrial processes of combustion, painting and varnishing, wastes utilization, deodorization, disinfection and sterilization, material processing and new material manufacturing for application in microelectronics and nanotechnologies. Non-thermal and non-equilibrium plasma based methods allow treatment of organic materials, like rubber, fabrics, biomaterials and they are ecologically justified alternative for chemical ones [1].

In Poland the plasma processes, although investigated in research laboratories, are applied in industry at much less scale than in industrialized countries [2]. In Poland in power industry (Pomorzany) the electron been technology is used for NO_X and SO_X decomposition [3]. Polish power industry is based on fossil fuels combustion that emits pollution in the form of sulphur and nitrogen oxides, soot and ashes, necessary to utilize. Plasma technologies can be the reasonable alternative for chemical, gypsum based wet methods, environmentally noxious, but still applied in power industrial practice.

Investigations in the field of industrial application of plasma chemical methods, conducted in many research centres and universities in Poland and abroad, are now concentrated on obtaining controllable plasma parameters and chemical reactions in large volume of treated gases [4-8]. Repeatability of the plasma-chemical process depends on stability of plasma parameters, which influence the proper chemical reaction path. The main parameters: are the chemical composition of the plasma gas, its pressure, flow rate, geometry of plasma reactor and electrical parameters of power system, i.e. value and form of supply voltage, power, and frequency.

Arc discharge can be the source of non-thermal and non-equilibrium plasma at some conditions of power supply system, reactor electrodes' geometry and gas flow rate [9, 10]. The gliding arc discharge plasma is the example of this kind of low temperature plasma that can be generated in multi-electrode reactors at atmospheric pressure.

Gliding arc reactor considerably differs from other non-thermal plasma sources. The resistance of inter-electrode gap depends on the kind of gas, its flow rate, degree of ionization and it also changes its value in wide range during the single operation cycle. Moreover, the discharge is displacing through electrodes periodically starting from the thermal short arc in the least electrode distance and increases its volume and length with the fast gas flow and electrodes' distance growth. Plasma generated in the gliding arc reactor is in non-equilibrium state: the temperature of "hot electrons" (T_e) is much higher than gas temperature (T_g) [11].

This kind of source of high energy electrons without heating the plasma gas in the whole volume of plasma reactor chamber is essential for typical plasma chemistry applications.

II. EXPERIMENTAL SETUP

In experiment we use three electrodes gliding arc plasma reactor with additional ignition electrode (Fig. 1). Plasma is generated in the chamber of reactor in one of the processing gases: argon, nitrogen and air, at the atmospheric pressure. We use different gas flow rates - from 0.3 m^3/h to 3.5 m^3/h. The gas flow less than 0.5 m^3/h was used only for argon, in which discharge can be sustained at much lower voltage than in nitrogen and air. Diagnostic conditions and reactor geometry are given in table 1.

We use three power supply systems for gliding arc discharge plasma reactor. Each power supply system based on three phase transformers with different limbs' material and different ignition systems. The first is the "integrated" power supply system (Fig. 2a) based on transformers with the soft external characteristic. Using non-linearity of magnetic circuit we can obtain the integration of basic functions of power supply in one

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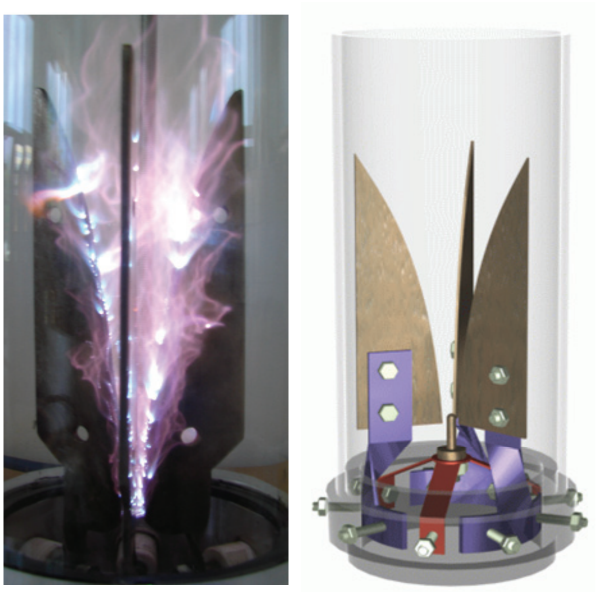

Fig. 1. Gliding arc plasma reactor.

TABLE I
WORKING PARAMETERS OF THE GLIDING ARC PLASMA REACTOR

Discharge chamber geometry	
chamber diameter	80 mm
electrode length	141 mm
electrode distance in the ignition area	1 - 6 mm
electrode distance in the extinction area	30 - 35 mm
Gas parameters	
process gases	argon, air, nitrogen
gas flow rates	0.3 – 3.5 m^3/h
Power supply system parameters	
inter-electrode voltage	400 – 1500 V
electrode current	1.0 – 3.5 A

device: preliminary ionization, ignition and sustaining the discharge during operation cycle, limitation of current value [12]. The second is the power supply system based on transformers with the amorphous limbs (Fig. 2b) with external ignition system. And the last is the power supply system based on five-limbs transformer with four winded cores in which the windings of external limbs are used to supply the ignition electrode (Fig. 3) [13].

III. RESULTS AND DISCUSSION

Chemical composition of the processing gas together with gas flow rate growth causes the changes of power transferred to the gliding arc plasma reactor. Power consumption as a function of gas flow rate is presented on Fig. 4.

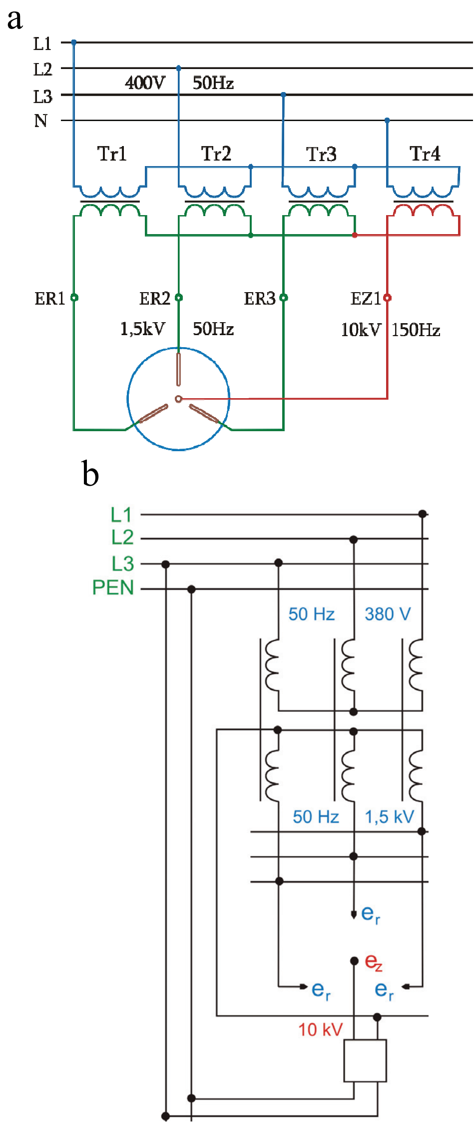

Fig. 2. Integrated power supply system.

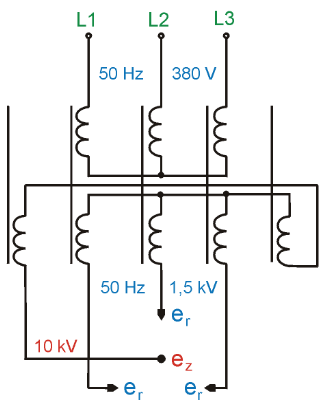

Fig. 3. Power supply system based on five-limbs transformer.

In case of argon as a processing gas, we obtained a linear power consumption characteristic. Otherwise, for nitrogen and air, the power consumption reduce with grows gas flow rate.

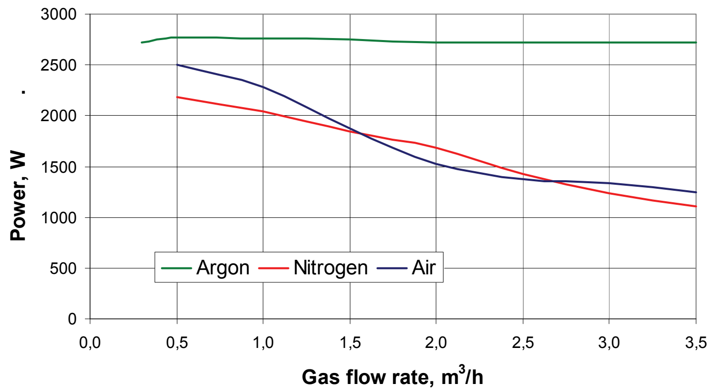

Fig. 4. Power consumption for different gases and flow rates
(power supply system based on transformer with amorphous limbs, primary windings voltage: 130 V).

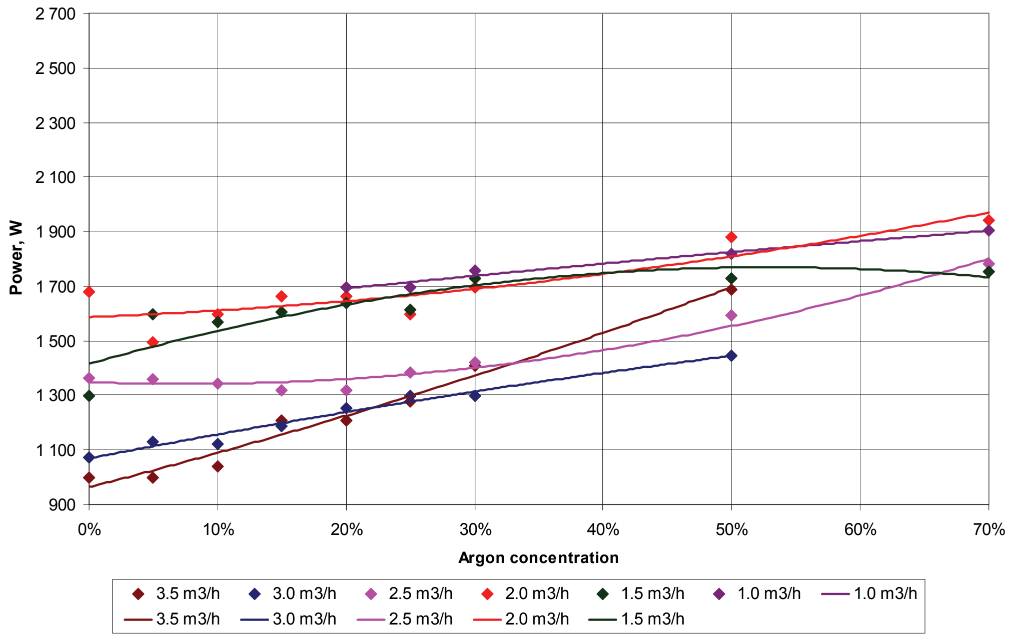

Fig. 5. Power consumption for various argon concentration in nitrogen
(power supply system based on transformer with amorphous limbs, primary windings voltage:130 V).

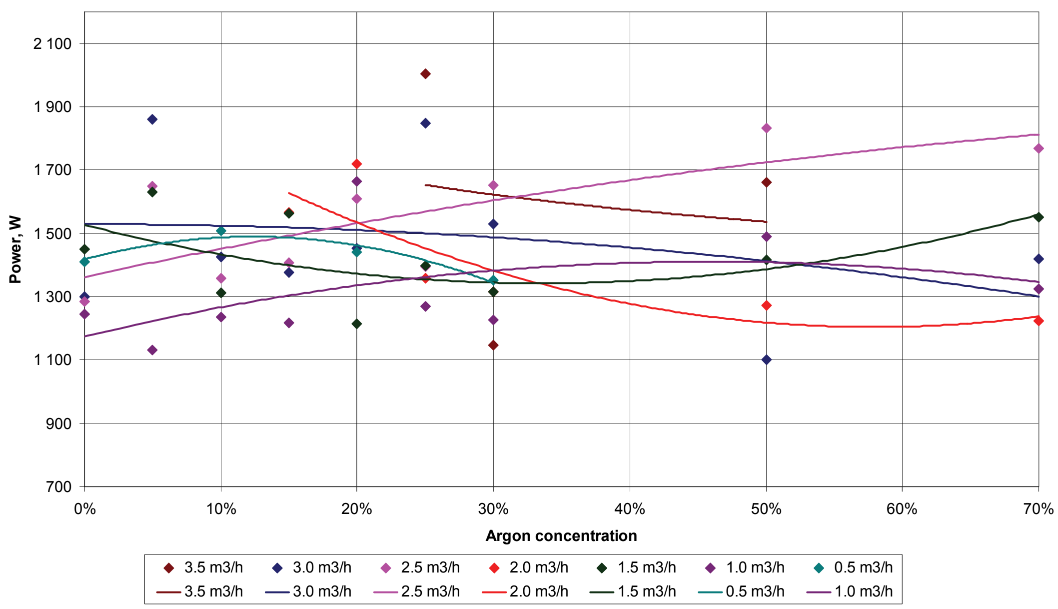

Fig. 6. Power consumption for various argon concentration in nitrogen (integrated power supply system, primary windings voltage: 230 V).

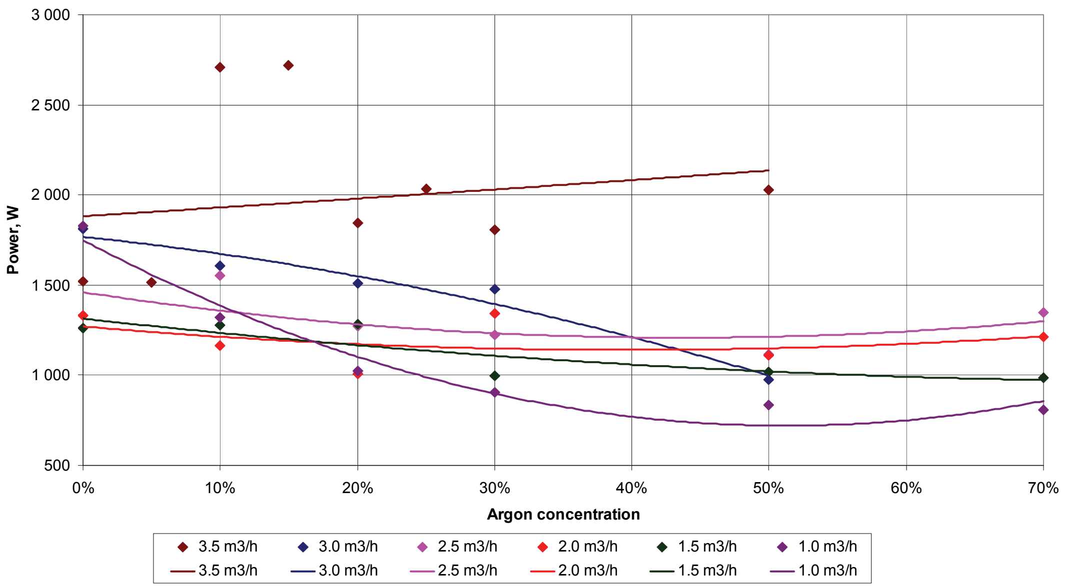

Fig. 7. Power consumption for various argon concentration in nitrogen (power supply system based on five-limbs transformer, primary windings voltage: 110 V).

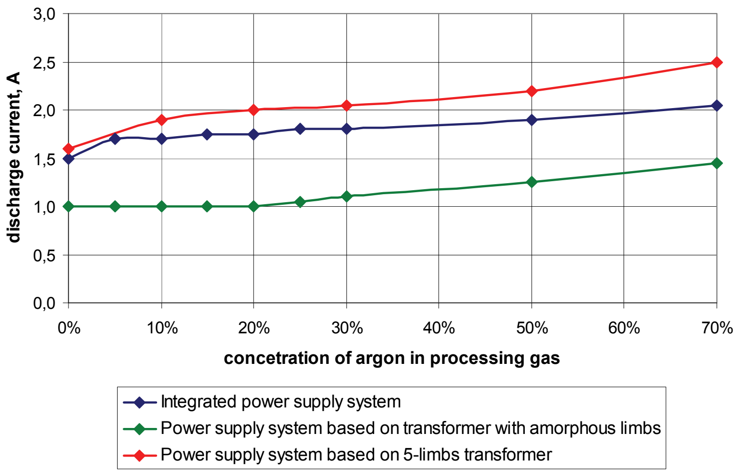

Fig. 8. Discharge current as a function of argon concentration in nitrogen for different power supply systems.

For the same power supply system we obtained power consumption for various argon concentration in processing gas (Fig. 5).

Increase of argon concentration in processing gas enlarge power consumption and stabilizes discharge, that is critical for low gas flow rates.

For integrated power supply system we obtained ignition at lower voltage, but for argon concentration in processing gas less than 30%, we observed discharge instability (Fig. 6).

We also observed close to linear characteristics of power consumption for different gas flow rates (in case of argon concentration in processing gas is greater than 30%).

For power supply system based on five-limbs transformer obtained results show, that power transferred to discharge increases with the increase of gas flow rate. Higher argon concentration in processing gas didn't affect to power and its only stabilize the discharge (Fig. 7).

We also measured the changes of discharge current for different power supply systems and various argon concentration in processing gas (Fig. 8).

For all power supply systems we observed increase the discharge current with the increasing of argon concentration in working gas.

IV. Conclusion

Power consumption of the gliding arc discharge plasma rector and its stable operation depends on many factors, among which the most important are: power supply system configuration [11, 14], processing gas flow rate and its chemical composition. Trace gases admixtures can essentially influence the plasma chemistry process. Argon admixture to the processing gas stabilizes the discharge and makes possible to transfer larger power from the power supply system to the discharge.

Correctly selected power supply system decides about plasma chemistry and technological application of this kind of non-thermal plasma.

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