Study of corona discharge characteristics of an ionizer for a compact electrostatically enhanced condensation system for pyrolysis gases

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In the modern society, the increase amount of plastic wastes has a negative impact on the environment. The pyrolysis technology is an effective way to upgrade plastic wastes.

The current study is focused on the development of a compact electrostatically enhanced condensation system for pyrolysis gases. Instead of separately maintained coolers and electrostatic precipitators it is supposed to design a compact system, which uses condensers equipped with corona discharge ionizers. Such design allows the lowing of the costs of the condensation system and the reduction of size and system complexity. The discussed results are focused on the optimization of design and operation parameters of the non-thermal plasma (NTP) ionizer for a compact condensation system. The NTP allows gas molecules activation in an energy-efficient way, as the gas does not have to be heated as a whole. Non-thermal plasma requires no pre-heating, long stabilization and cool-down times. NTP can be quickly turned on and off.

The developed pilot corona discharge ionizer included a tube grounded electrode, which simulated the condenser inner tube. A high voltage (HV) rod was axially installed inside the grounded tube, being equipped with star-form HV electrodes used for generation of corona discharge. The current-voltage characteristics (CVC) of the corona discharge were measured in air, pure gases (He, N_2, CO_2) and gas mixtures. Study was carried out for positive and negative polarity of applied voltage. The "direct" and "indirect" CVCs were measured assuming increase and decrease of applied voltage at constant operation conditions. Taking into consideration, that the ionizer should be operated in hot pyrolysis gases, the tests were carried out for variable temperatures of the grounded tube electrode, which was electrically heated. The test facility allowed the experiments to be carried out at the temperature of the ionizer up to 650°C and variable gas pressure inside the facility. The Fourier-transform infrared spectrometer was used to control gas composition inside the test facility.

The results of the tests show, that during the same time interval, the negative polarity corona allows higher discharge energy densities, than the positive one. The increase of air pressure results in decrease of corona current at constant applied voltage. The gas composition plays a decisive role for corona discharge characteristics. It was defined, that in the gas mixture N_2 is "responsible" for hysteresis and He "moves" the hysteresis curves to higher gas pressures. The use of hysteresis allows the optimization of ionizer operation parameters taking into consideration the variability of applied voltage, corona current and power consumption. For the CVCs, measured in the gas mixture CO_2:He:N_2 (Figure 1), at constant applied voltage, the current for "indirect CVC" was higher than for "direct" CVC. At constant applied voltage, at the beginning, corona discharge power consumption increases and then exponentially decreases (Figure 2). After ~1 h, the corona discharge power consumption was ~4 times lower, than previously measured maximum value, what means the change of gas composition inside the facility.

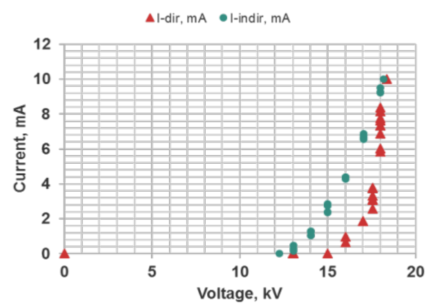

Figure 1. Negative polarity corona discharge CVC, CO_2 19,0%: He 10,3%: N_2 70,7%

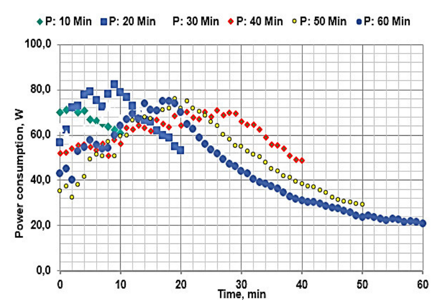

Figure 2. Time dependence of corona discharge power consumption, CO_2 68,7%: He 16,4%: N_2 14,9%

The results of tests are used for the design of the ionizer of the compact electrostatically enhanced condensation system for pyrolysis gases.