Contact Glow Discharge Electrolysis in the presence of Organic Waste

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Abstract. The present experimental study was conducted to analyze the interaction between contact glow discharge electrolysis and biomass. For comparison, two sets of tests were conducted, first in the absence of biomass and second in the presence of biomass. It was observed that when limited electrolyte was present in the liquid, the process of normal electrolysis did not transition to contact glow discharge electrolysis. Addition of biomass to the liquid, increased the overall concentration of electrolyte and the process transitioned to contact glow discharge electrolysis after a critical current density was reached near the electrode with smaller surface area. Further, it was observed that most of the energy was consumed in generating steam instead of performing gasification of biomass.

1. Introduction
The field of waste-to-energy conversion using thermal plasma is growing rapidly. A review of current technologies along with performance comparisons of different waste gasification processes based on thermal plasma is presented by Fabry et al. [1].

One of the many useful products of such gasification process is syngas, a mixture of carbon monoxide and hydrogen along with small amounts of other gases. Rutberg et al. [2] evaluated high temperature plasma gasification of wood for the production of syngas. They reported energy conversion ratio of 46.2% approximately, from primary energy of wood with moisture content of 20% (LHV 13.9 MJkg⁻¹) into electric.

Huang & Tang [3] conducted thermal plasma pyrolysis of different kinds of organic wastes, varying from plastic and used tire to agricultural residue and medical waste.

Recently Sharma et al. [4] studied contact glow discharge electrolysis as an efficient means to generate steam from liquid waste. In order to prevent the formation of an electric arc between the electrodes, a non-conductive material (gravel) was introduced. In the present study contact glow discharge electrolysis [5] was generated in electrolyte with and without biomass to analyze the feasibility of gasification of biomass with this process.

2. Experimental setup
Experimental setup consisted of a stainless steel cylinder acting as anode and a partially immersed graphite rod acting as cathode as shown in Fig. 1. Tap water with and without biomass was used as electrolyte for the two different experiments.
Power was supplied by an ESP-150 DC power supply manufactured by ESAB with control console designed by Foret Plasma Labs. The power supply had a current range between 0 and 150 Amperes and a maximum voltage of 380 Volts. Current output was controlled by a potentiometer knob on the control panel. A National Instruments™ data acquisition system was used along with NI LabVIEW™ to record current, voltage, and temperature with a sampling rate of two seconds. Current values were measured with a Veris direct current sensor model H970HCA with a maximum current range of 200 A and ±3% of accuracy at full scale. Voltages were read directly from a remote control voltage pin on the power supply.

3. Experimental procedure
The stainless steel container acting as anode was filled with tap water until the electrode was submerged to about 5 cm. No biomass was added in the first case. The potentiometer knob at the power supply panel was set to quarter the scale and it remained fixed during the experiment. The potentiometer limited the amount of current passing between the electrodes but the power supply allowed variation of voltages and currents depending on the physical parameters of the process. As no electrolyte was added to the tap water, the amount of ions was relatively low. The cell went into normal electrolysis mode after the power was supplied. Because of Joule heating, water started to evaporate and the effective submerged area of cathode decreased due to the lower liquid level in the container. Because of limited amount of ions, the current density near the cathode never crossed the threshold and the process remained in normal electrolysis mode until the cathode lost contact with water.

In the second case, a measured amount of biomass (dry almond hulls) was added to a fresh refill of tap water to the same level as in the previous case. The biomass added electrolyte to water which was close to room temperature in the beginning of the experiment. The electrolytic cell started in normal electrolysis mode and the electrolyte began to heat due to Joule heating resulting in a higher rate of evaporation that lowered the electrolyte level, thereby, decreasing the submerged length of the cathode and further increasing the electrical current density near the cathode. At a critical value of the current density and when the...
electrolyte temperature near the cathode approached its boiling point, normal electrolysis in the cell transitioned to contact glow discharge electrolysis.

4. Results and discussion
4.1. In absence of biomass
At the start of the experiment, tap water was at room temperature. The amount of electrolyte present in tap water was limited since no extra electrolyte was added. As the experiment progressed, the temperature of the tap water increased due to Joule heating. The electrical conductivity of electrolyte increased with temperature [6] and resulted in an increase in the current as shown in Fig. 2 (a). The voltage across the electrode stayed almost constant at 350V as shown in Fig. 2 (b).

![Figure 2. Variation of current, voltage, and temperature with time in the absence of biomass.](image)

Joule heating increased the temperature of water until it reached a value near the boiling point of the water as shown in Fig. 2 (c). Current followed the variation in temperature closely and reached a maximum value when temperature reached its maximum. As the length of submerged cathode continued to decrease and the amount of electrolyte present in water was limited, this resulted in further decrease in current until the cathode lost contact with water. With the decrease in current, Joule heating decreased which is reflected in the decrease in temperature after 4500 secs into the test.

4.2. In presence of biomass
Dried almond hulls were added to a fresh refill of tap water to the same level as before. At the start of the experiment, electrolyte was at room temperature. As the experiment progressed, the temperature of the electrolyte started to increase due to Joule heating and biomass added extra electrolyte to the tap water, the electrical conductivity of electrolyte was higher than in the previous case which resulted in overall higher current levels. Electrical conductivity also increased with temperature and resulted in an increase in the current and corresponding decrease in voltage between the electrodes as shown in Figs. 3 (a) and (b).

As the temperature of electrolyte increased, the rate of evaporation increased causing the length of submerged electrode to decrease. This resulted in an increase of electrical current density at the cathode as sufficient electrolyte was present. The normal electrolysis process ceased and contact glow discharge electrolysis was established at a current value of 21 A and when the temperature of the electrolyte near the cathode reached its boiling point as shown in Figs. 3 (c). Formation of vapor film around the cathode increased overall resistance of the cell and resulted in the characteristic drop in current at the transition. No sign of biomass gasification was observed during the glow discharge process but large amounts of steam was generated.
Figure 3. Variation of current, voltage, and temperature with time in the presence of biomass.

5. Conclusions
The experiment was designed to test the feasibility of carrying out gasification using contact glow discharge electrolysis in the presence of biomass. Two different cases were tested, with and without biomass. In the absence of biomass, the electrolysis never transitioned to glow discharge because of limited presence of electrolyte. Biomass added electrolyte to tap water and resulted in transition from normal to glow discharge electrolysis. It was observed that most of the heat was absorbed by water to produce steam. Even though biomass was present close to the high temperature, the experiment did not result in any appreciable gasification. In conclusion, the energy dissipated at the cathode was absorbed by the surrounding liquid which was converted into steam. A significantly lower amount of liquid would be needed in order to produce the gasification of the biomass.

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