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Powering Fuel Cells with Crude Oil

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Abstract

Over the last few decades the demand for energy has increased significantly. Energy production is based mainly on coal, crude oil, natural gas and nuclear energy. Over the last few years alternative energy sources have been developing. One of these sources are fuel cells (FC), mainly due to their high efficiency. FCs convert chemical fuel directly into electrical energy without combustion. Generally FCs are powered by hydrogen. However, problems with the storage of hydrogen are driving a search for new FC friendly fuels. The paper presents the possibility of using crude oil as a fuel for FCs. As crude oil does not have the feature of electrical conductivity, a detergent—nonionic surfactant—was used to dissolve oil in an electrolyte.

The work explores electrooxidation of a crude oil emulsion prepared on the basis of a nonionic surfactant on a platinum electrode in an aqueous solution of H_2SO_4. The resulting current density reached 10 mA/cm^2, at a potential of about 1.30 V, which clearly demonstrates it is possible to use crude oil as a fuel for FCs.

Keywords: fuel cells, electrooxidation, crude oil, fuel

1. Introduction

As living standards rise, so does energy consumption. The massive increases in demand seen over the last few decades, among other causes, have left the power sector struggling. Energy production is generally based on coal, crude oil, natural gas and nuclear energy. In recent years there has been an upsurge of interest and research in alternative energy sources such as photovoltaic cells, solar panels, heat pumps and wind turbines. One of these sources is FCs, mainly due to their high efficiency. The principles of operation of the FC has been known from 1839 [1]. The theoretical efficiency of a reversible galvanic cell can reach 100%. In fact, actual efficiency varies in the range 40-80%. In addition, FCs feature zero or low negative impact on the environment and silent operation. Generally, FCs are powered by hydrogen [2–4]. However, problems with storage of hydrogen are driving a search for new fuels for FCs [5–8]. This paper presents the possibility of using crude oil as a fuel for FCs.

FCs converts chemical fuel directly into electrical energy, without combustion. The efficiency of the fuel cell can be calculated from Eq. (1).

$$\eta = \frac{\Delta G}{\Delta H} = 1 - \frac{T\Delta S}{\Delta H} \tag{1}$$

Eq. (1) shows that the efficiency of the cell depends on the magnitude and sign of entropy. From the equation we see that if for the reaction in a fuel cell $\Delta H > 0$ and $\Delta > 0$, then the thermodynamic factor of efficiency is $\eta < 1$ and it decreases as the temperature increases [9].

The maximum energy of chemical conversion of the energy into work is equal to the free energy reac-

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tion (2) [10]

$$\Delta G = \Delta H - T\Delta S \tag{2}$$

Changing the Gibbs free energy ΔG associated with the cell electromotive force E° is represented by the relation (3)

$$\Delta G = -nFE^\circ \tag{3}$$

By transforming Eq. (3) we obtain

$$E^\circ = \frac{-\Delta G}{n \cdot 96.4kJ} \tag{4}$$

Electromotive force depends on the entropy change of the reaction ΔS and for different reactions is presented in the following equations [11]

$$O_2 + 2H_2 = 2H_2O_{(liquid)} \rightarrow 1.23 \tag{5}$$

$$O_2 + 2H_2 = 2H_2O_{(gas)} \rightarrow 1.19 \tag{6}$$

$$2CO + O_2 = 2CO_2 \rightarrow 1.33 \tag{7}$$

2. Results

Crude oil is a hydrophobic substance and does not conduct electric current. To enable conduction an intermediate agent to disperse crude oil in water was used. SYNTANOL DS-10 was used as a detergent. SYNTANOL DS-10 is a mixture of primary oxygen-ethylene-glycol ethers of fatty alcohol of C_{10}-C_{18} fraction. The investigated emulsion was obtained by mixing, in various ratios, crude oil, detergent and water, using a mixer at a speed of 1,200 rpm. Stabilization time was 12 hours.

Research was done by using the method of polarizing curves of electrooxidation of the crude oil emulsion in a glass vessel, on a smooth platinum electrode. The research was performed by selecting catalysts which do not contain precious metals, but the results obtained do not at this point allow for a proper catalytic property [12–14]. For measurements a platinum electrode was selected, as it has very good catalytic properties. A mercuric electrode was used as a reference electrode. Research was done in a glass cell on the potentiostat AMEL System 5000. This paper presents research into electrooxidation of the emulsion based on crude oil in an acid electrolyte, for various concentrations of crude oil and detergent, and at various temperatures (20...65°C). Previous studies indicated the choice of electrolyte for the emulsion of crude oil [15]. The focus is therefore on an acid electrolyte.

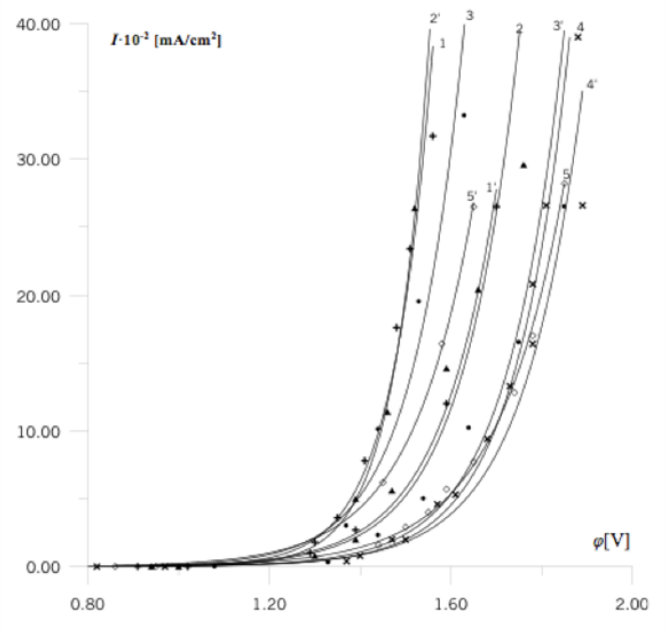

Figure 1: Polarization curves of electrooxidation of detergent SYNTANOL DS-10 (1'-5') and 0.01% emulsion of crude oil (1-5) in various concentration of electrolyte (H_2SO_4): 1,1'—0.01N; 2.2'—0.05N; 3.3'—0.1N; 4.4'—1.0N; 5.5'–5.0N

In the first emulsion of crude oil, when $\Delta S \approx 0$, from the calculation we obtain E°=1.39 V.

Fig. 1 shows the polarization curves of electrooxidation of a 0.01% emulsion of crude oil and detergent SYNTANOL DS-10 in various concentrations of electrolyte (at 40°C).

Fig. 2 shows the polarization curves of electrooxidation of an emulsion of crude oil in various concentrations of crude oil in 0.1n concentration of electrolyte (at 65°C).

The potential of the examined electrode was establishing in a time period from 15 to 20 minutes and was poorly reproducible. Stationary, current-free potential depends on crude oil concentration and is included in potentials ranging from 0.9...1.1 V.

To ascertain that the emulsion and not the detergent was electrooxidated, research into the electrooxidation process was done in the scope of kinetics, but the potential on the electrode is low and establishes over a long period of time. The highest results of potential were obtained for acid electrolyte at the temperature of 40°C. At 40°C the rate of electrooxidation of a crude oil emulsion is greater than the rate of electrooxidation SYNTANOL DS-10. With the increase in temperature to 65°C first the electrooxi-

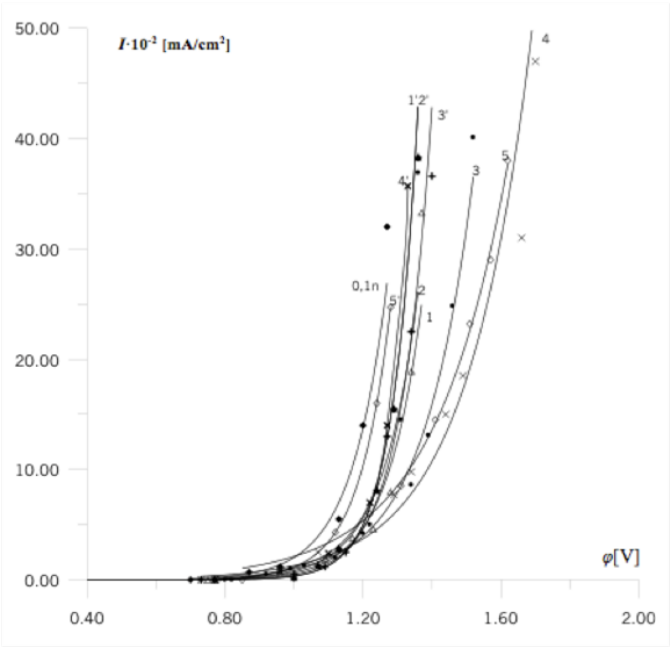

Figure 2: Polarization curves of electrooxidation of detergent SYNTANOL DS-10 (1'-5') and an emulsion of crude oil (1-5) in 0.1n concentration of electrolyte H_2SO_4 (at 65°C): 1.1'—0.0025%; 2.2'—0.005%; 3.3'—0.010%; 4.4'—0.025%; 5.5'—0.050%

dation of SYNTANOL takes place, and only then of the crude oil emulsion.

3. Conclusions

The fundamental possibility of electrooxidation of crude oil on a smooth platinum electrode in acid electrolyte is shown in this paper. It has been demonstrated that using detergent to prepare the emulsion of crude oil allows for the electrooxidation of crude oil, and thus the possibility of direct conversion of crude oil into electrical energy. In the first emulsion of crude oil, when $\Delta S \approx 0$, from the calculation we obtain E°=1.39 V. Measurements showed current intensity I of 10 mA with potential φ=0.9 V from 1 cm^2 of smooth surface platinum electrode. The highest results of potential were obtained for acid electrolyte at the temperature of 40°C. Future studies will make it possible to identify the substances that were left after crude oil electrooxidation.

The fundamental possibility of powering FCs with crude oil has been demonstrated (with acid electrolyte) as has a possible construction (COil-FC). Further reseach is required into selection of catalysts for COil-FC and selection of proton exchange membranes (PEM) to work alongside emulsions of crude oil.

Nomenclature

FC	—fuel cell
COil	—crude oil fuel cell
PEM	—proton exchange membrane
ΔG	—change in Gibbs free energy, kJ/mol
ΔH	—change in enthalpy, J/kg
T	—absolute temperature, K
ΔS	—change in entropy, J/K
n	—number of electrons involved in the electrode reaction
F	—Faraday constant per volt gram equivalent, kJ
I	—current intensity, A
φ	—electrode potential, V
E°	—cell electromotive force, V

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