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FUEL CELLS AS PERSPECTIVE ENERGY SOURCES

Different devices using as the source of energy in the limit of cities. especially monumental cities have been analysed in this paper. The criterion T has been used in the carried out analysis.

Ecological requirements for energy utilization, especially in the monumental cities, are as follows: no production of harmful gases (CO, NO_x, SO_2), no noise, operational reliability and high efficiency factor. The best way to fulfil the above requirements is direct conversion of chemical energy of a fuel into electric power [1].

An ordinary galvanic cell contains some volumes of active components which by their nature establish limits for the lifetime of such a cell. In a fuel cell (FC), the active components (i.e. fuel and oxidiser) are supplied continuously and hence the lifetime of a cell is not defined by the stock of active components contained in a FC. That feature makes an essential advantage of FCs. For that reason it is not by chance that high - temperature fuel cells have been suggested as stand - by sources of power for space ships [2].

It is well known from thermodynamics [31 that the maximum work done can be defined as

$$A_{max} = -\Delta G$$

where a change of the isobaric potential ΔG results from a chemical reaction occurring in an electrochemical system. The value of Amax can be presented as:

$$A_{max} = q \cdot E$$

where E = electromotive force (EMF) and $q = z \cdot F$ volume of electricity conducted through that system (F— Faraday's constant). Then:

$$E = \Delta G/zF$$

According to the second principle of thermodynamics:

$$\Delta G = \Delta H - T\Delta S$$

and hence

$$E = -\Delta H/zF + T\Delta S/zF$$

When molar enthalpy (ΔH) and molar entropy (ΔS) are known for the course of a reaction electromotive force can be calculated for a fuel cell. The efficiency factor for a FC can be calculated from the equation:

$$\eta = -\Delta G/\Delta H = 1 - T(\Delta S/\Delta H)$$

That can even approach 100% when the reaction does not result in any change of the number of moles of a gas, e.g.

$$C + O_2 = CO_2 \ (\Delta S = 0)$$

Utilisation of low-temperature fuel cells faces a number of difficulties. Limitations appear at low temperatures (for aqueous electrolytes) which are imposed by the rules of kinetics. Moreover, the system suffers from considerable polarisation losses which result from the formation of hydrogen peroxide at the oxygen-gas electrode [4]. Whenever considerable power is required from a cell, noble metals are frequently needed to be utilised [7,8].

Fig. 1. Fuel cells- 1kW. PSPL-2 (National Univesity I. I. Mechnikov, Odessa)

Fig. 2. Fuel cells- 50kW (Fuell cells 2002,2, No.1)

Making use of FCs is possible in many ways.
-diesel- electric drive. A car is equipped in two engines: petrol or oil engine (used beyond the limits of cities) and electric motor (used in the limits of cities). The power of fuel cells drives ranges from 6 to 600 kW;
-emergency power supply (hospitals, banks, telegraphs, runways, ports. railway stations, etc.). The power required in such cases is about several hundred kW; ---power supply for mobile equipments (floating beacons, probes, airports equipment, radios, TV sets, mobile telephones, etc.)
The following criterion has been used for the global evaluation of different devices using as the source of energy in monumental cities

$$T = \sum_i g_i T_i$$

where: gi- weight function and Ti- estimated parameter.
Seven parameters have been taken into account: specific power [*kW/kg*], specific energy [*kJ/kg*], power obtained from the unit of volume [*kW/l*], efficiency factor, practica application, service conditions and resources.
Value of the weight functions can be estimated in many ways. The best of them seems to be the method of relative characteristics (with reference to the best devices in group for each of them the value of the g, was assumed to be 1).

The operational safety, wastes utilization can be evaluated by the another criterion:

$$u = \sum u_i^{P_i}$$

where parameters u_1, u_2, u_3, u_4, refer respectively to: waste gases, noise, operational safety and wastes utilization. Equation (9) consists of the terms of u_i^{Pi} because each of the parameters ui affects on the final value of the u to the different degree (for instance waste gases may be harmful or even lethal). Estimating the parameter it, we ought to take into account content of the CO, Pb and hydrocarbons. In order to estimate the parameter u_2 the noise of 70 dB (typical in the centre of a big city) was assumed as the unit. Then for a diesel engine with the power of 100 hp u2 =0,1-0,55, for a diesel engine with the power of 2500 hp u_2= 0,55-0,75. For galvanic cells and FCs u_2= 1. Values of the parameter u3 range from 0,6 to 1. Even for FCs in which gasoline or hydrogen are used as the fuel the value of the parameter u3 is sufficiently high (u_3= 0,8-1,0). One of the most important parameters is utilization of wastes, wt. For example the amount of the carbonizate residues for FCs with an alkaline electrolyte is about 600 l/y. The same quantity for FCs with acid electrolyte is much lower. Values of the parameter u_4 for the FCs range from 0,6 to 1,0.
The price of power devices is also as much important factor as their technical characteristics T and u.
The possibility of utilizing gases or liquids (hydrogen, oxygen, methanol, ammonia, etc.) as the active components (i. e. fuel and oxidiser) in FCs instead of expensive materials like metals or their compounds is the main advantage of using these power devices. In the FCs metals are needed only as the structural component. For example, the metal consumption by the hydrogen - air FC is about 100 times lower in comparison with galvanic cells and more than ten times lower for the case of rechargeable cells. Additionally, the metal consumption in the case of FCs can be reduced to the level of 1 g per 1 kWh of energy produced.
The price of power devices production consists of three components:
-Capital expenditure. There is no information about the investment costs in the case of the FCs. Therefore for a rough evaluation the price of the catalyst (with regeneration) is taken into account.
Generally speaking, electrochemical sources of energy (FCs, galvanic cells, rechargeable cells) are still much more expensive then engines with inner combustion.
-Operating costs, consist of labour costs, spar part costs and costs of the energy lost. Operating costs are much lower for electrochemical devices, which do not posses moving parts, than for engines with inner combustion.
-Proportional costs. The main part of these costs consists both of the price of fuel and oxidizer.

Table. Proportional costs

Device	Fuel	Fuel consumption, kW/kg	Fuel price, grn/kg	Fuel costs, grn/kW·h
1.Gas engine	Petrol, A-95	0,30-0,45	21,0	9,5
2.Diesel	Diesel fuel	0,20-0,25	20,0	0,8-1,0
3.Fuel cell	Hydrogen	0,05	200,0	50
	Alcohol (Methanol)	0,45	10,0	-4,0
	Liquid hydrocarbons	0,25	3,0-3,5	1,0
4.Oxidizer	O2	1,2	1,0	0,2

The total price of 1 kWh of energy produced can be calculated from the formula [5,6]:

$$S=F+K(1/\tau+P)/zf+k/H\eta$$

where: F- Operating costs, K- investment costs calculated per 1 kWh of the maximal power, τ- resources (years), p- interest rate, z- the number of work-hours per year, f — service load (the radio of the mean working power and the maximal power) $0\leq f\leq 1$, K- price of the fuel's unit, H- specific temperature of the fuel combustion, η- efficiency factor as a function of the service load f.

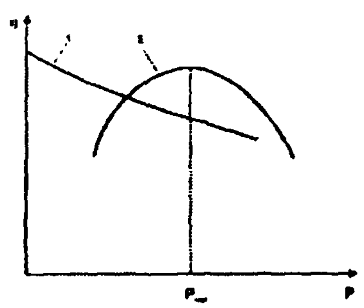

Fig. 3. Efficiency factor as the function of the power.
1- FC; 2- diesel

The function $\eta=\varphi(t)$ obtained for FCs essentially differs from those obtained for other energy sources. The functions obtained for FCs are monotonically decreasing (Fig. 3). For other energy sources the efficiency factor achieves the maximum for the maximal value of the power or in close neighbourhood of this value. Thus for engines with inner combustion

$$d\eta/df\geq 0$$

and for FCs

$$d\eta/df<0$$

Using Equation (10) we can calculate the derivative dS/df:

$$ds/df=-K(1/\tau+P)/(zf^2)-k/H\eta^2 d\eta/df$$

From the above equation results that the total price S decreases with increasing the service load f, when $d\eta/df \geq 0$. If $d\eta/df < 0$ the second term of Equation (13) is positive and the extremal value of the S exists.
If $d^2S/df^2 > 0$ the S possesses minimum. Thus, there exists for FCs such a power value for which the total price of 1 kWh of energy produced achieves the minimal value. Therefore; the FCs application is necessary for such a case when mostly a rated power is needed but periodically maximal power is expected. The engines with inner combustion do not operate under optimal conditions for the case described above.
Examples:
-Land transport. The PC achieves the best value of the criterion T (0,76). The most typical Otto's engines achieve T=0.68 That relatively low value of the criterion 7' is caused both by the high value of the practical application (T_i=0,1) and by the low value of engine's power needed in the limits of cities. For city buses (mass of 16 t, velocity of 60 km/h, mileage 130-150 km/day, specific power of 0,28 kW/kg, specific energy of 0,38 kWh/kg) the highest value of criterion T achieve: the FC, the Stirling's engine and steam engine. For this case the diesel engine achieves the lower value of the criterion T (noise, pollution, high value of practical application)
-Small power engineering. The main requirements: a low value of a time of a continuous work ("weight" 0,5), a low value of both mass ("weight" 0,3) and volume ("weight" 0,15), a high value of the efficiency factor ("weight" 0,05). For this case, the maximal value of the criterion 7' is achieved for the FCs. The carried out analysis shows that FCs are the optimum source of energy in the limits of cities especially in the monumental cities.
For numerous applications FCs seem to be more perspective than the engines with inner combustion.

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