PRODUCTION OF ACETYLENE FROM METHANE IN A HYDROGEN PLASMA JET[1])

W. W. PŁOTCZYK[2]), A. SZYMAŃSKI[2]), Warszawa

The effect of the flow rate of hydrogen which has been designed for stabilizing the arc discharge on the electrode voltage, on the constant-current plasmotron efficiency and on the yield of the methane-to-acetylene conversion has been studied for various anode diameters and for arc power values ranging from 25 to 100 kW.

ОБРАЗОВАНИЕ АЦЕТИЛЕНА ИЗ МЕТАНА В ПЛАЗМЕННОЙ СТРУЕ ВОДОРОДА

В работе исследовано влияние расхода водорода, стабилизирующего электрическую дугу плазмотрона постоянного тока, на потенциал электрода, кпд плазмотрона и на единичный расход энергии в процессе образования ацетилена из метана. Эксперименты проведены для различных диаметров анода при мощности дуги в интервале от 25 до 100 кВт.

1. INTRODUCTION

Introduction of methane into a plasma jet makes it possible to obtain acetylene as the main reaction product [1—5]. The plasma jet is produced in electrode plasmotrons; their heat efficiency η depends on the carrier gas volume V_{H_2}, and on the anode nozzle diameter, d. It can be concluded both from thermodynamic considerations and from experimental data [5—7] that the unit consumption energy of acetylene, Z, depends on the flow rate of the carrier gas as well as on the plasmotron efficiency. The efficiency can depend in various ways on the volume flow rate of hydrogen [3—6].

The effect of the volume flow rate of hydrogen on the energy consumption has been calculated for the discharge power equal to 30 kW and for various dependences of efficiency on the amount of hydrogen by the method elaborated for the argon plasma process [8].

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[2]) Department of Chemistry, Warsaw University, Pasteura 1, 02-093 WARSAW, Poland.

The calculations have shown that:

— If the efficiency is independent of the flow rate of hydrogen or if the dependence is weak, then the energy consumption increases with the increasing amount of hydrogen;

— A clear decrease in the unit energy consumption appears if η increases rapidly with V_{H_2};

— Lower energy consumption values correspond to higher plasmotron efficiency values.

As it can be observed, an increase in the plasmotron efficiency due to an increase in the amount of the arc discharge stabilizing gas in some cases only leads to a decrease in the energy consumption.

II. EXPERIMENTAL METHODS

The apparatus and the measurement method used in the experiments were described earlier [9]. The anode diameter has been varied from 6.5×10^{-3} m to 20×10^{-3} m and that of the reaction chamber from 1×10^{-2} m to 1.8×10^{-2} m. The arc has been stabilized by a constant current magnetic field. A three-phase ac rectifier with the current control by means of chopping coils has been employed at arc power values exceeding 50 kW.

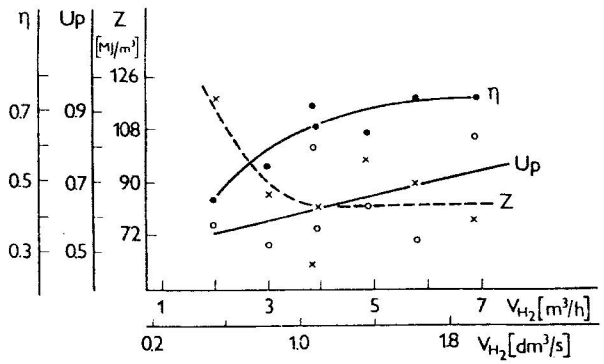

Fig. 1. Dependence of the process parameters of acetylene synthesis from methane on the amount of hydrogen stabilizing the arc discharge.

III. RESULTS AND DISCUSSION

In the first stage the effect of the volume flow rate on the energy consumption and on the degree of the methane-to-acetylene conversion has been studied at the 25 kW arc power using an anode with a 10^{-2} m diameter and a graphite reaction chamber of the same diameter. The results are presented in Fig. 1.

It can be observed that there is a clear decrease in the energy consumption in the range where the efficiency is high (0.6—1.2 dm³/s). A further increase of the hydrogen amount does not change the plasmotron efficiency and, consequently, causes no lowering of the energy consumption. It can also be observed that an increase of the hydrogen amount provokes an increase in the degree of the methane-to-acetylene conversion, U_p. Under such conditions, the content of acetylene in the reaction products gradually decreases from 12 to 8 %.

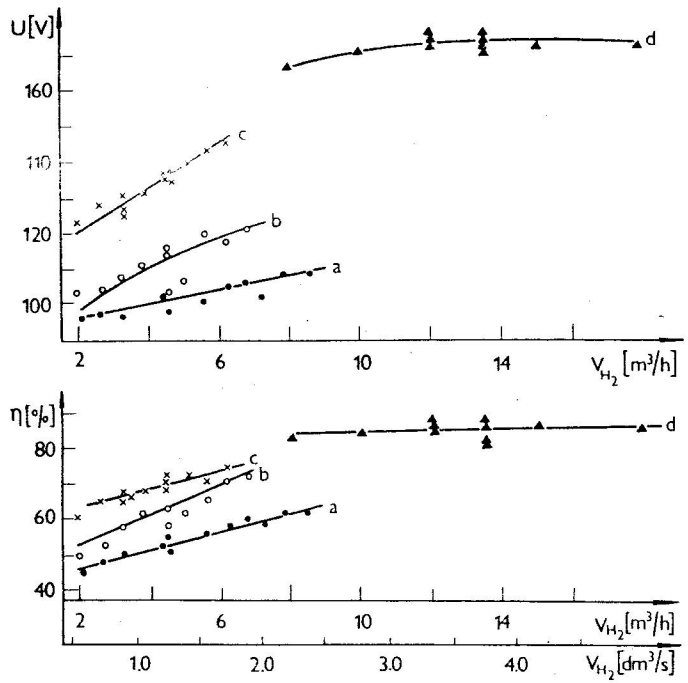

Fig. 2. The effect of amount of hydrogen stabilizing the arc discharge on the plasmotron parameters for the anode diameters: a — 4.5 mm, b — 8 mm, c — 12 mm, d — 18 mm.

Thereafter, the effect of the volume flow rate of hydrogen on the plasmotron parameters has been checked for various anode diameters at a 230 A current (Fig. 2, curves a-c). There results from the curves that an increase in the anode diameter causes a considerable increase in the voltage U acting between the electrodes and in the plasmotron efficiency. It can be observed in Fig. 2 that an increase in the anode diameter causes a more pronounced increase in the plasmotron efficiency than an increase in the amount of hydrogen. In addition, it allows to attain a higher arc power and increases the plasmotron durability. Consequently, the experiment

designed to attain the 60 kW arc power has been carried out using an anode with a 1.8×10^{-2} m diameter; the current has been increased to 350—375 A and the volume flow rate of hydrogen to 2.2—4.6 dm³/s (Fig. 2, curve d). It can be seen that a high plasmotron efficiency exceeding 80 % has been attained. According to the model calculations it should lower the unit energy consumption of the acetylene from methane. This conclusion is supported by the data presented in Table 1 where

Table 1

Results of experiments on the synthesis of acetylene from methane in a hydrogen plasma jet

The parameter	1	2	3	4	5
M [kW]	51.34	60.12	61.22	61.06	59.15
V_{H_2} [dm³/s]	2.22	2.22	2.77	3.33	3.75
V_{CH_4} [dm³/s]	2.77	2.77	3.33	3.88	3.88
η [%]	81.7	83.4	84.6	85.4	86.1
Z [MJ/m³ C_2H_2]	70.9	67.7	74.9	64.8	71.6
% C_2H_2 [% vol]	12.7	13.7	10.5	9.8	9.5
% CH_4 [% vol]	15.5	9.4	15.1	11.0	14.6
U_p [%]	52	64	49	48	42

Table 2

The results of experiments carried out using an anode with a 2×10^{-2} m diameter

Parameter	1	2	3	4	5	6	7	8	9
I [A]	398	410	440	460	400	423	432	420	465
U [V]	228	214	206	220	240	236	235	242	238
M [kW]	90.7	87.7	90.6	101.2	96.0	99.8	101.5	101.6	110.7
V_{H_2} [dm³/s]	4.16	4.16	4.16	4.16	4.99	4.99	4.99	5.54	5.54
η [%]	83.3	76.5	75.6	77.0	88.4	87.4	87.8	87.8	89.7

the results of an experiment with a copper anode and reaction chamber, both with a 1.8×10^{-2} m diameter, are presented. The energy consumption values ranging from 65 to 75 MJ/m³ C_2H_2 attained there using a diaphragm cooling of the reaction products should be estimated as being promissing, although the yield of the methane-to-acetylene conversion has not been high. An increase in the plasmotron power to over 100 kW has been attained by simultaneously increasing the anode diameter, the flow rate of hydrogen and the arc current. The results are shown in Table 2. As it can be seen, the attained plasmotron efficiency values have been high (76—90 %).

IV. CONCLUSIONS

It has been demonstrated that an increase in the volume flow rate of hydrogen does not lower the energy consumption of the process of the acetylene synthesis from methane unless it is accompanied by a rapid increase in the plasmotron efficiency. A more effective way to increase the efficiency is to increase the anode diameter rather than the amount of hydrogen. An increase in the plasmotron power should be done by simultaneously increasing the anode diameter, the volume flow rate of hydrogen and the arc current.

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