EXPERIMENTAL INVESTIGATIONS OF THE HYBRID PLASMA TORCH WITH REVERSE VORTEX STABILIZATION*

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In the article results of investigation of a reverse vortex hybrid plasma torch were described. The hybrid plasma torch is a combination of RF plasma torch and arc plasma torch. In this kind of torch reverse vortex gas stabilization was used to increase an efficiency of plasma energy. At the start operational mode arc plasma jet is used for the ignition of RF plasma. It was shown that hybrid plasma torch works successful with different plasma gases, and its characteristics is better than the arc plasma torch and RF one have shown each taken separately.

Key words: hybrid plasma torch, reverse vortex gas stabilization.

1. INTRODUCTION

Waste treatment is one of the most widespread areas of plasma technologies. Broad practical application of plasma in such technological processes is described by its properties as heat-transfer agent with high concentration of energy. Arc (DC) and radio-frequency (RF) induction electrical discharges are used in the industry for generation of plasma.

Arc plasma torch does not provide necessary parameters of plasma for technological process. Main problems of DC torches are plasma jet pollution by material of electrode erosion and short time of continuous work.

Unique technical characteristics of RF plasma torch in comparison with arc plasma torch are: plasma generation in a large volume; cleanness of plasma due to no-electrodes; simplicity of a design; possibility of wide change of a plasma velocity; simplicity of in-feeding into plasma; big time of material staying in plasma jet; long lifecycle; reliability in operation; workability various gases, including aggressive ones; possibilities of power scaling up to 10 MW.

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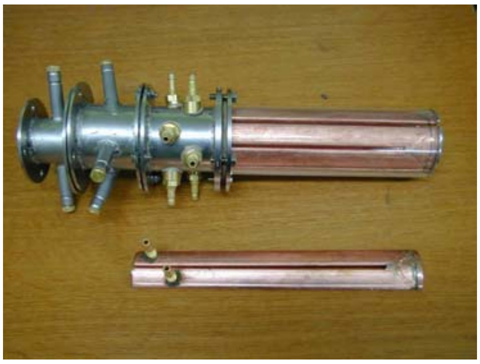

Fig. 1 – Metal water cooling RF plasma torch.

Radio-frequency induction plasma torch is intended for generation of non-electrode pure plasma in an atmosphere of various gases: air, argon, nitrogen and other. RF induction plasma torch consists of the following basic elements: metal water-cooling sections (fingers); quarts tube; body-corpus and gas former (see Fig. 1, one section of the metal water-cooling chamber is presented separately).

2. REVERSE VORTEX HYBRID PLASMA TORCH

Reverse vortex RF plasma torch has the high efficiency of plasma energy. Therefore reverse vortex hybrid plasma torch has been chosen for experimental studies [2]. Reverse vortex hybrid plasma torch is combination of RF plasma torch and arc plasma torch. Schematically and visually hybrid plasma torch is presented on Figs. 2 and 3. Technical parameters of hybrid installation are resulted in Table 1.

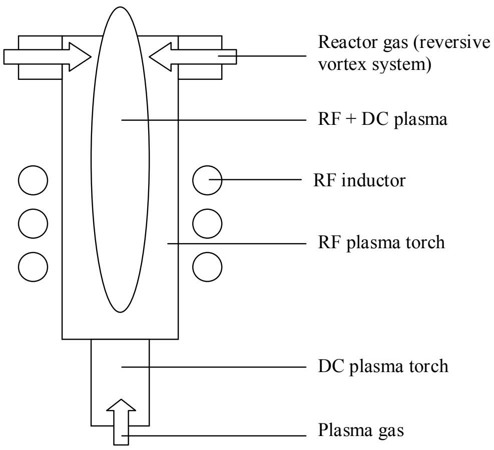

Fig. 2 – Layout of the hybrid (RF + DC) installation.

Fig. 3 – Hybrid (RF+DC) plasma torch (assembled).

Table 1

Adjectives of the experimental setup

Parameter	Value
Working frequency of the tube generator	5.28 MHz[1]
Power of the RF plasma torch	15…25 kW
Power of the arc plasma torch	10…15 kW
Weight-average temperature at the outlet cross-section of the plasma torch	5500 K
Type of a plasma gas	Air, Argon, Nitrogen
Gas flow rate	1…3 g/s

[1] This value was taken from the standard line of frequencies regimented for the industrial high frequency plants in Russian Federation.

There are some procedures of ignition of RF plasma. It has been found experimentally that the arc plasma torch is the simplest embodiment for RF plasma ignition. Consequently arc plasma torch is used for ionization of gas-discharge area (see Fig. 4). Also arc plasma torch is used for preliminary waste heating. For air arc plasma the thermochemical hafnium electrode was installed. For argon and nitrogen arc plasma the lanthanum tungsten electrode was installed.

In the realized prime experiments it has been studied the following hybrid torch properties and conditions:

1. Parallel start-up of DC and RF plasma torches.
2. Stability of the RF + DC discharge at the expense of gas flow effect.
3. Durability of the RF + DC discharge at the expense of power effect.
4. Maximum available gas flow at the expense of output RF torch diameter.
5. Durability of the RF + DC discharge at the expense of reverse gas both for arc torch swirler, and for RF torch gas former.

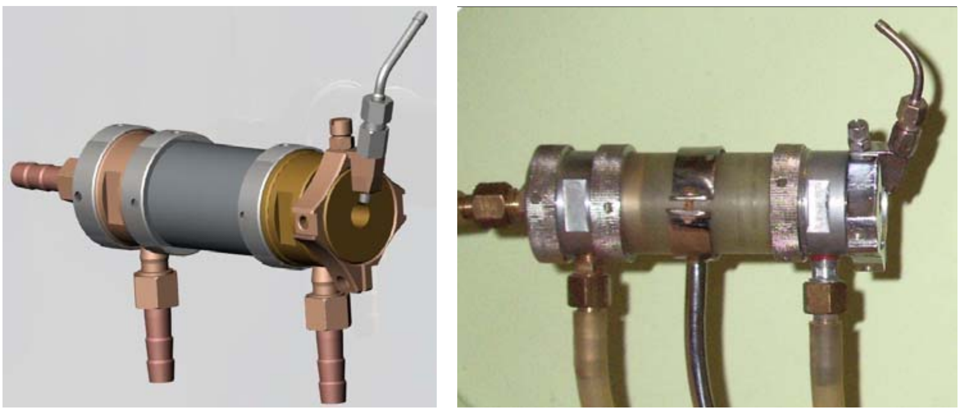

Fig. 4 – Arc plasma torch: 3D model and photo.

As a result it was possible to achieve total gas flow through hybrid torch equal 3 g/s in a mixture of plasma gas. Namely, gas flow rate through RF torch was 1.5 g/s and gas flow rate through DC torch was 2 g/s.

Ignition modes of hybrid torch were realized on next step. But the main goal of these experiments was studying of stability of the RF + DC discharge for pure air and nitrogen plasma gas under the condition that total gas flow was equal 3 g/s (it is maximum allowed gas flow received in the previous experiments).

It was found that ignition of discharge using pure air or nitrogen is not possible. Therefore plasma ignition occurred on argon, and then carried out connection and transition to pure air or nitrogen plasma gas. Breakdowns between coils of inductor arose in transition on air or nitrogen regularly. Transient process is the primary cause of these breakdowns because the gas change is accompanied by variation of plasma conductivity that provides an overvoltage on the inductor coils. To achieve avoiding of breakdowns the inductor coils were isolated by a protective cover.

3. EXPERIMENTAL RESULTS

Summary results are presented in Table 2. Visualizations of reverse vortex hybrid plasma torch operating modes in various atmospheres are presented on Figs. 5–7.

Table 2

Experimental data of hybrid torch investigations

Gas	Parameters and modes of RF plasma torch				Parameters and modes of DC plasma torch			
	U_a	I_a	P_{RF}	G_{RF}	U	I	P_{DC}	G_{DC}
	kV	A	kW	g/s	V	A	kW	g/s
Argon	6.5	5.5	16	0.4-1.5	140	80	11	1.6-2
Air	6.5	5.5	16	0.8-1.5	100	100	10	1.2-1.5
Nitrogen	7.5	7	25	0.4-1.5	140-175	80-100	14	0.5-1

Selection of operational conditions of RF and DC plasma torches by computational simulation is performed (see Fig. 8).

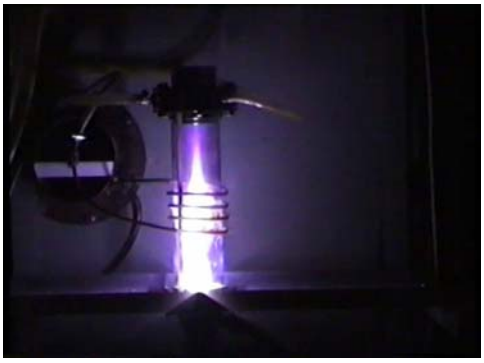

Fig. 5 – Argon combined operation mode of hybrid (DC + RF) plasma torch.

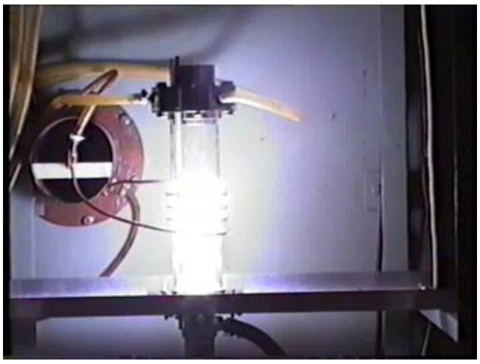

Fig. 6 – Air combined operation mode of hybrid (DC + RF) plasma torch.

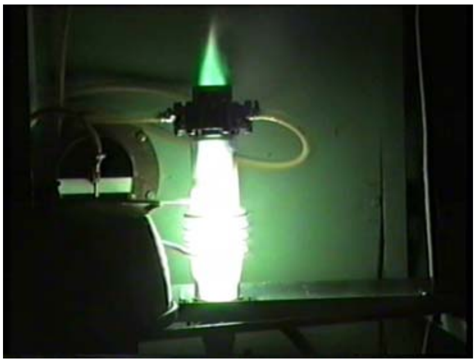

Fig. 7 – Nitrogen combined operation mode of hybrid (DC + RF) plasma torches.

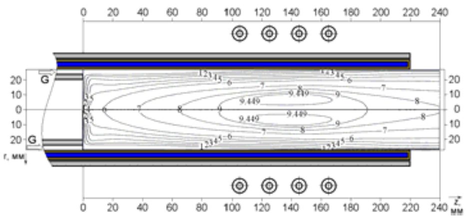

Fig. 8 – Typical distribution of plasma temperature in RF plasma torch.

4. CONCLUSIONS

1. Positive effect of hybrid (DC + RF) plasma torch combined operation mode in an atmosphere of various gases has been achieved.

2. Maximum gas flow through hybrid torch was equal 3 g/s. This rate has been defined experimentally.

3. Now there is a work on by designing reversive vortex hybrid (DC + RF) plasma torch with copper water-cooling chamber. In further is planned to increase power of hybrid plasma torch.

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