GEOMETRIC DIMENSION FOR THE GENERALIZATION OF PLASMATRON CHARACTERISTICS

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In generalizing the volt-ampere characteristics and efficiency data for floating-arc plasmatrons, the diameter of the output channel is usually taken as the linear characteristic dimension. At present, the problem concerning the effect of the diameter on the plasmatron characteristic has still not been solved even for the simplest design schemes.

This study deals with the effect of the diameter on the volt-ampere characteristic and efficiency of a one-chamber plasmatron with any type of arc stabilization. A description of the equipment and experimental technique is given in [1].

For this study, geometrically similar plasmatrons were prepared with anode-channel diameters of 4, 8, 16 mm and a relative output-electrode length $l/d = 10$ (d is the electrode diameter).

Possible deviations from geometric similarity in the arc-channel system were not taken into account; deviations from hydrodynamic flow similarity in the eddy chamber had an insignificant effect on the arc-formation process.

The table gives the basic experimental data for the tested plasmatron. The similarity criteria were determined from the mean-mass temperature and the static pressure at the channel outlet. This method of generalization which has been used before in [1] makes it possible to allow approximately for the change in the physical properties with heating.

The figure shows the generalized volt-ampere characteristic obtained from the experimental results. The experimental points on the figure correspond to the following pairs of experimental values for G (g/sec) and p_2 (mm Hg): 1 (0.62, 760), 2 (0.82, 146-255), 3 (1.05, 752), 4 (1.03, 84-106), 5 (1.78, 745), 6 (1.65, 42-44).

With a spread of ±12%, the data fit the relationship [1]

$$\frac{Ud}{I} = 1 \cdot 10^4 \left(\frac{I^2}{Gd}\right)^{-3/4} R_d^{-0.5}. \tag{1}$$

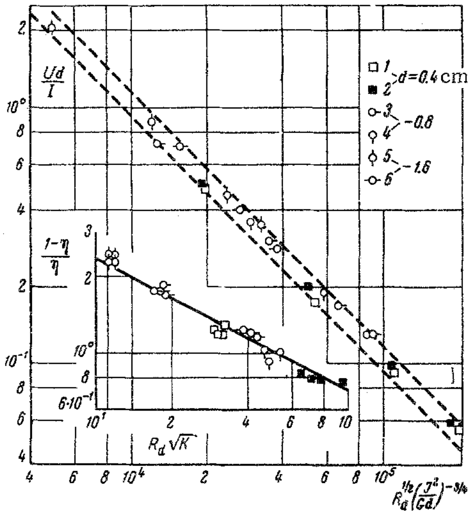
Here R_d is the Reynolds number, I is the arc current, G is the gas flow rate, and U is the voltage. The experimental data cover the range of values

$$R_d \approx 4 \cdot 10^2 - 1 \cdot 10^4, \qquad I^2/Gd \approx 0.3 \cdot 10^3 - 1 \cdot 10^5.$$

The volt-ampere characteristic in this generalization is invariant with respect to the diameter.

U, V	I, A	G, g/sec	P_2, mm Hg	η	T, °K	$R_d 10^{-3}$	$K \cdot 10^4$	d, cm
28.6	24.2	0.63	760	0.44	1220	3.34	0.90	
22.8	52.8	0.63	760	0.46	1990	2.51	1.60	
21.4	94.6	0.62	760	0.46	3180	1.88	2.67	
22.0	154.5	0.61	760	0.45	5140	1.28	4.88	0.4
29.2	24.8	0.84	146	0.57	1230	4.37	4.95	
26.0	52.3	0.83	189	0.56	2060	3.22	5.92	
23.3	94.6	0.82	232	0.56	3060	2.56	7.70	
22.4	153.5	0.80	255	0.55	6080	1.68	14.25	
34.3	33.6	1.04	752	0.37	1000	3.13	0.38	
29.3	74.6	1.05	752	0.37	1780	2.23	0.71	
27.4	125.0	1.05	752	0.37	2630	1.78	1.09	
25.6	160.1	1.06	752	0.35	2880	1.71	1.20	0.8
33.0	73.3	1.02	84	0.50	2580	1.75	9.37	
30.2	123.2	1.03	99	0.52	3920	1.36	13.00	
27.0	167.4	1.04	106	0.49	4410	1.24	14.50	
42.8	32.3	1.78	745	0.30	745	3.22	0.14	
36.5	65.4	1.78	745	0.30	1080	2.53	0.21	
31.2	108.0	1.78	745	0.29	1330	2.21	0.28	
30.5	138.0	1.78	745	0.29	1630	2.00	0.33	1.6
39.0	86.6	1.65	42	0.46	2100	1.58	7.70	
32.0	129.0	1.65	44	0.45	2470	1.46	8.56	
29.2	166.0	1.65	44	0.45	2820	1.34	10.00	

The conclusion drawn in [1] regarding the effect of the breakdown condition on the efficiency is a particular case since only the change in gas density was considered. Experiments with plasmatrons of various diameters have made it possible to obtain a clear estimate of



the effects of this factor on arc formation. The figure also shows $(1 - \eta)/\eta$ as a function of $R_d (K)^{1/2}$, where K is the Knudsen number.

Clearly, the experimental data can be satisfactorily generalized in this coordinate system. However, a more detailed consideration shows that there is evidently an additional weak effect introduced by the linear dimension of the plasmatron. This may possibly be due to some impairment in the internal geometric similarity with respect to the position of the electrode spot and eddy formation in the chamber.

The physical meaning of the term $R_d (K)^{1/2}$ for a laminar boundary layer at the plasmatron chamber walls is still not quite clear. Formally, we can consider this term, for example, as representing the existence of some effective linear scale $d^* = (d\Lambda)^{1/2}$, where d is the controlling dimension and Λ is the mean free path.

The thermal characteristic of these plasmatrons can be given by the expression

$$(1 - \eta)/\eta = 7.2 (R_d \sqrt{K})^{-1/2}, \tag{2}$$

which is accurate to within ±15%.

On the basis of the obtained relationship it is easy to analyze the effect of the anode diameter on the thermal losses under different conditions.

REFERENCES

1. S. S. Kutateladze, A. K. Rebrov, and V. N. Yarygin, "Effect of convective heat exchange on plasmatron characteristics," PMTF [Journal of Applied Mechanics and Technical Physics], no. 1, 1967.

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