THE INFLUENCE OF GAS-INLET AND QUENCHING SYSTEMS ON THE NITROGEN OXIDES PRODUCTION IN AIR PLASMA

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ABSTRACT

A model equation for nitrogen oxides synthesis in air plasma stream is presented. It was elaborated by methods of dimensional analysis. The coefficients have been calculated on the basis of experiments, using the range of average rates of air flow. The influence of gas-inlet and plasma-quenching systems have been taken into the consideration.

1. INTRODUCTION

In previous contributions, presented at the III-th and IV-th Symposiums on Plasma Chemistry, the influence of quenching system and oxygen-nitrogen mixture composition on the final yield of nitrogen oxides synthesis in the plasma jet has been shown and discussed /1,2/. In several series of experiments relatively high concentrations of the product have been obtained, but they never were higher than the optimal value calculated for equilibric conditions. On the other hand it was shown /3,4/, that plasma jet is always a non-equilibric system and the concentration of products of chemical processes taking place in it may be calculated correc tly only on the basic of a kinetic model. For nitrogen oxides synthesis, according to that assumption the highest final concentration should be ca. 11% instead of 7% calculated by thermodynamical methods. Our experimental data have been obtained in the range of average rates of flow. However in that conditions we could not obtain the highest non-equilibric concentrations, assumed in the kinetic model. For us the NO-concentrations of 5,5 - 6,5 % are interesting enough for the attempt to describe the process in the form of a phenomenological equation. This form may be probably useful for the design of a developed plant.
It has been found, that for the stability of the reactor materials the gas-inlet system is important. It is also well known, that the quenching system determines the rate of the decomposition of NO, formed in plasma. In the present paper the influence of the change of the both systems on the values of equation coefficients has been taken into account.

2. EXPERIMENTAL

A device for air plasma generation, described in the precedent paper, has been used as a basic system /2/. The device has been modified by the introduction of copper water-cooled rings between the nozzle and the anode and by a new quenching-system /fig. 1/.

So in the series of experiments the influence of the length of the reaction chamber on the result of nitrogen oxides production has been studied. In these conditions the same power of arc-discharge has been obtained at various voltage-current ratios. The construction of the cathodic chamber mode it possible to realize two methods of air inlet: axial or tangential. The outlet plasma has been quenched in the nozzle with two inlet slits with various possibilities of using quenching agents. Oxygen or oxygen and water have been introduced /fig.2/. In the experiments the following values of the variables have been determined: the rate of air flow: 2...6 m^3/h, the length of reaction chamber 0,017...0,037 m, the chamber diameter 0,004 or 0,005 m, the power of discharges 7...55 kW.

3. RESULTS

First, the stability of the reactor materials has been taken into the consideration. It was found, that from that point of view the tangential gas-inlet system is more favorable than the axial one. For the construction of a phenomenological equation the dimensional analysis has been introducted. As the preliminary assumption the following relation is proposed:

$\dot{m}_{NO} = f/U, I, \dot{m}, p, d, L, \varrho, \eta, h/$

where:

$\dot{m}_{NO}$ - the rate of flow of NO /$kg\ s^{-1}$/
U - arc voltage /$m^2 kg\ s^{-3} A^{-1}$/
I - the current intensity /A/
$\dot{m}$ - the rate of air flow /$kg\ s^{-1}$/
p - the gas pressure /$m^{-1} kg\ s^{-2}$/
ϱ - the density of the inlet gas /$m^{-3} kg$/
d - the diameter of the nozzle /m/
L - the length of the nozzle /m/
h - the gas enthalpy /$m^2 s^{-2}$/
η - the coefficient of the viscosity /$m\ kg\ s^{-1}$/

As a conclusion an equation, containing only criterial numbers has been obtained:

$$\frac{\dot{m}_{NO}}{\dot{m}} = A \left[\frac{U \cdot I \eta r}{\dot{m}\ h}\right]^{a_1} \left[\frac{\dot{m}}{d\ \eta}\right]^{a_2} \left[\frac{\eta \sqrt{h}}{p\ d}\right]^{a_3} \left[\frac{L}{d}\right]^{a_4}$$

This equation can be reduced by the introduction of parameters which are constans in all experiments /h, η/. In such a way we obtain the following equation:

$$r_{NO} = A \left[e_u\right]^{a_1} \left[\frac{\dot{m}}{d}\right]^{a_2} \left[p \cdot d\right]^{a_3} \left[\frac{L}{d}\right]^{a_4}$$

where:

r_{NO} - the nitrogen oxides concentration
e_u - effective energy
η_r - reactor efficiency

The values of coeffocoents are presented in the table 1,
The equation gives a satisfactory apprpximation of the experimental data indicated in the range of variability of parameters. The results of the experiments are shown in the fig. 3 - 5.

4. CONCLUSION

A phenomenological equation for nitrogen oxides synthesis in air plasma jet, obtained in set-up with changed cathode-anode distance has been presented. Using various gas-inlet and quenching-systems it has been found, that at average rates of air flow the concentration of nitrogen oxides depends as much on the quenching system as on the mode of gas-inlet. Using double water- or oxygen quenching system, as well as combined water-oxygen system, the highest conversion of inlet air /approx. 8%/ has been obtained in case of double oxygen injection.

REFERENCES

/1/ I. Pollo: The III-th Symposium on Plasma Chemistry, Limoges 1977, G-1.9
/2/ I. Pollo., K. Hoffmann, L. Fedeńczuk: The IV-th Symposium on Plasma Chemistry, Zurich 1979, Proceedings 361
/3/ P. Fauchais, J.M. Baronnet: ibid. 336
/4/ J.M. Baronnet, J.F. Coudert, J. Rakowitz, E. Bourdin, P. Fauchais: ibid. 349

table 1

gas -inlet system	d /m/	L /m/		A	a_1	a_2	a_3	a_4
axial	0,004	0,017-0,027	H_2O	1,092	0,847	0,191	-0,224	0,273
tangent-ial	0,005	0,017-0,037	H_2O	3,084	0,621	0,600	-0,242	0,486

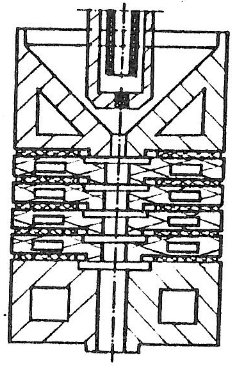

fig. 1.The schema of the set-up

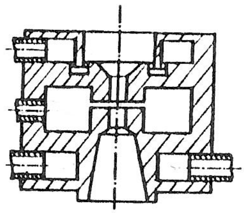

fig. 2.
The quenching system

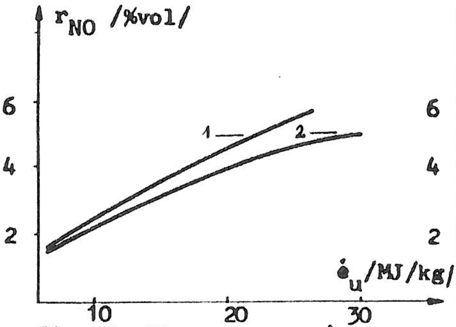

fig. 3. NO-conc. v s $\dot{e}_u$ by different mode of gas-inlet

1 - axial

2 - tangential

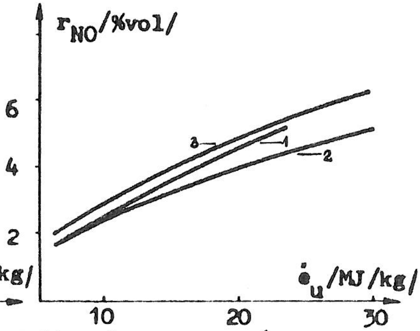

fig. 4. r_{NO} v s $\dot{e}_u$ by different quenching system

1 - double H_2O

2 - $H_2O + O_2$

3 - double O_2

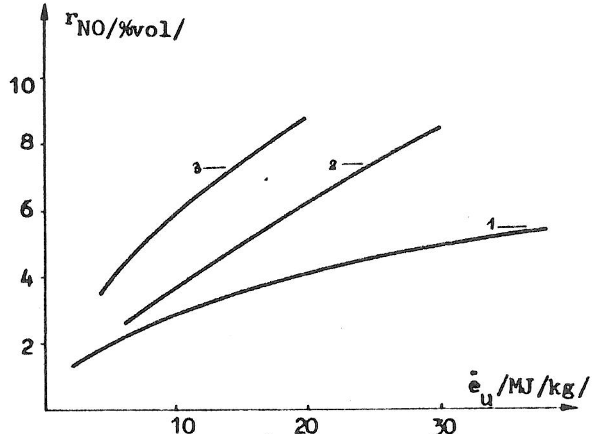

fig. 5. r_{NO} v s $\dot{e}_u$ by different length of reaction chamber

1 - L = 0,017 m

2 - L = 0,022 m

3 - L = 0,027 m