

OPTIMIZING IGNITION AND COMBUSTION OF FUELS TO THE NAVAL STEAM GENERATORS

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Abstract: *The continuous damage of the used fuel quality, of its dispersion due to the increasing viscosity, make necessary the volume expansion and the rise of the electric spark power used at ignition. A similar situation appears to the transition of the generator operation from the marine Diesel heavy fuel to the residues of water-fuel mixture. So, it feels like using an ignition system with high specific energy and power able to perform the starting and burning of the fuels mentioned above. Such a system is that which uses a low temperature plasma jet. Its use involves obtaining a high temperature area round about the jet, with a high discharge power, extending the possibility of obtaining a constant burning of different concentration (density) mixtures. Besides the action of the temperature of the air-fuel mixture, the plasma jet raises the rate of oxidation reaction as a result of appearance of lot number of active centers such as loaded molecules, atoms, ions, free radicals*

Keywords: fuel, viscosity, burning, plasma jet.

1. INTRODUCTION

The ignition of air-fuel mixtures in the burning points of marine steam generators is performed under certain conditions of temperature and pressure, usually from an energy (power) source formed of an electric spark of high voltage 10-15 kV.

The reaction taking place at the level of swirling plasma jet lead to the generation of an overbalance concentration of atoms and free radicals (H, CH₃, O, OH) and to large quantities of products which couldn't change (couldn't take part in the oxidation reaction), such as CO, H₂.

The use of plasma jet for ignition and burning reduces the ignition delay time, raises the fuel combustion (burning) speed, giving stability to burning. As a feature of combustion process of hydrocarbons in the plasma jet is that their burning assumes the performance of thermal pyrolysis and dissociation (decomposition) as well as the generation of nitric acid and some cyanide components in the combustion products. At the plasma temperature of 3000° K the essential reactions lead to an overbalance of hydrogen atoms as part of the plasmochemical reactions.

It can assume that, in case of the plasmochemical reactions, a high swirling burning is generated at the level of plasma jet (plasma-fuel), containing a large quantity of active products, having in the same time a high temperature and a direct influence upon the hydrocarbon oxidation in the air-fuel mixture.

2. THE PHYSICO-CHEMICAL PRINCIPLES OF BURNING START UNDER THE PLASMA JET OF OIL FUELS

Through the heat conducted (transmitted) by the plasma jet to the burning fuel, its combustion speed rises, due to the intensification (enhancement) of heat transfer (flow) from the jet to the air-fuel mixture. It is of interest the general case, namely, the heat action of plasma jet at the burning of one oil fuel drop. The burning/combustion process of a drop includes three distinct stages:

- self-ignition delay generated by heat transfer (flow) to the drop till the reacting boiling point (temperature);
- burning of transient (volatile) components in the drop and generation of ecosphere;
- the cenosphere burning; provided that the heat transfer from them environment to the drop is performed by convection and radiation; the drop temperature can be determined by the following formula:

$$\frac{dT_k}{dt} = \frac{6}{\rho_k \cdot d_k \cdot c_{pk}} \left[\frac{\lambda_g \cdot N_u \cdot (T_g - T_k)}{dk} + h_1 + h_2 \right]; \quad (1)$$

in which:

$$N_u = 2 + 0,56 \cdot R_e^{0,5}; \quad R_e = \frac{\rho_k \cdot d_k \cdot |V_g - V_k|}{\mu_t}; \quad (2)$$

and

$$h_1 = 4,6 \cdot 10^{-5} \cdot I \cdot \frac{p}{\pi \cdot d_2}; \quad h_2 = a_g \cdot a_k \cdot (T_g^4 - T_k^4); \quad (3)$$

where:

- r_k, d_k – are the density and the diameter of the drop;
- c_{pk} – thermal conductivity of fuel;
- l_t – thermo conductivity coefficient of the environment;
- m_t – viscosity;
- I – heat intensity of plasma jet;
- p – pressure;
- s – Stefan Bolhzman constant;
- a_g – air emission factor from the determination stand;
- a_k – the blackening degree of drop surface $a_k=0.05-0.30$ for heavy fuels.

The variation of drop diameter as a result of the evaporation and burning processes of the volatiles can be expressed by:

$$\frac{dd_k}{dt} = \frac{-2}{\rho_k \cdot N_u} \cdot \left[\frac{\lambda_g \cdot N_u (T_g - T_k)}{d_k} + h_1 + h_2 \right]; \quad (4)$$

in which:

$$N_u = N_{u0} \cdot H_1; \quad H_1 = \frac{\ln(1+B)}{B}; \quad (5)$$

$$B = c_{pg} \cdot (T_g - T_k) / H_N;$$

where:

c_{pg} – is the thermal conductivity of fuel vapors at $p=ct$;
 H_N – heat necessary for fuel vaporization.

The temperature of the drop can be determined by:

$$T_k = T_f + K_p + \left[1 - \left(\frac{d_k}{d_{k0}} \right)^3 \right]; \quad (6)$$

where:

T_f – boiling temperature;
 k_p – factor of proportionality;
 d_{k0} – the initial diameter of drop;

Supposing that the burning of coke formed is developed on the entire surface of the drop and from the point of view of physical phenomenon it is an oxidation of carbon, we can write:

$$\frac{dd_{cox}}{dt} = \frac{0.75}{\rho_{cox}} \cdot k_x \cdot C_{o_2}; \quad (7)$$

where:

k_x – is the constant of chemical reaction rate;
 d_{cox}, ρ_{cox} – the diameter and the density of coke particles;
 C_{o_2} – represents the oxygen amount necessary for burning a particle of coke.

$$C_{o_2} = \frac{0,21 \cdot p}{R_{o_2} \cdot T_g}; \quad (8)$$

where:

R_{o_2} – excess of burning air.

The motion equations to the axial and radial direction for the fuel drop with spherical symmetry passing through all the burning stages are given by:

$$\frac{d_{vz_k}}{dt} = \frac{6\mu_g}{8\rho_k \cdot d_k^2} \cdot (V_{z_g} - V_{z_k}) \cdot c_d \cdot Re_k ; \quad (9)$$

$$\frac{dv_{rk}}{dt} = \frac{6\mu_r}{8\rho_k \cdot d_k^2} \cdot (V_r - V_{r_k}) \cdot c_d \cdot Re_k ; \quad (10)$$

-in witch the resistance (consistency/strength) coefficient of the drop is given by:

$$c_d = 27 \cdot Re^{-0,84} - \text{for } Re_k \leq 80;$$

$$c_d = 0,271 \cdot Re^{0,271} - \text{for } 80 < Re_k < 10^4;$$

$$c_d = 2, - \text{for } Re \geq 10^4;$$

-the viscosity coefficient of gas is determined by:

$$\mu_g = \frac{0,012 \cdot (d_3 \cdot \rho_{pa})^{\frac{2}{3}} \cdot l_3}{(G_{pa} \cdot V^2 z_{pa})^{\frac{1}{3}}} ; \quad (11)$$

where:

l_3 – is the length of the anode plate of the experimental system.

r_{pa} , G_{pa} – are the density and the plasma consumption of the experimental system.

The set of the differential equations has been resolved by RUNG-KUTT method determining the axial and radial coordinates such as:

$$Z_k = Z_{k_0} + \int_0^t V_{z_k} \cdot dt ; \quad (12)$$

$$r_x = r_{k_0} + \int_0^t V_{r_k} \cdot dt. \quad (13)$$

The tests (experiments) have been performed for three types (classes) of fuel: fuel oil, marine Diesel heavy and light fuels. In Fig. , there are presented the variations of drop diameter and Reynolds number for loads of plasma generator $G_p = 0,1; 0,2; 0,5; 1,0; 2,0 \cdot 10^3$ kg/s.

3. CONCLUSION

On the increase of burning air consumption, the burning time of fuel drops rises because of the reductive of plasma temperature and also the heat received by fuel drop. For the curves 1 and 2 we care evidently see the variation of drops diameter according to the three stages of burning (combustion). The dependence of complete (perfect) combustion of fuel drops on the intensity of voltaic arc for generating of plasma is given in Fig . It can be seen that the time of perfect combustion t^n is suddenly reduced on the increase of the intensity of voltaic arc up to the value of 10 A, then its reduction is not important when the intensity of voltaic arc increases up to 24 A. An essential factor of total time of combustion is the initial diameter of the drops (the quality of atomization). When the drop diameter increases from 50 to 300 μm , the combustion time rises 6-7 times.

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