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THE COMBUSTION PARAMETER OF THE MARINE HEAVY LIQUID FUELS, SIMPLE AND WATER EMULSIFIED FUEL

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Abstract : *To determine the parameters necessary for making a comparation between the naval residual heavy fuels burning, simple and with water in emulsion, used in marine power systems, we conceived a computer program to establish the composition of combustion gases and combustion point on the diagram, in which the combustion processes can be interpreted and cams to the conclusions regarding to the fire control. The ARDIAG program determines the amount of CO and CO_2 from flue gases, the combustion point on the diagram, for liquid heavy fuel simple and with water in emulsion.*
Keywords: *naval heavy fuels, emulsion, gas burning, burning.*

INTRODUCTION

The determination of gravimetric participations of fuel for emulsified fuels

Depending on the water amount being found in the marine water-fuel emulsion [W_f], its gravimetric shares, the gravimetric shares, the fuel is determined by:

$$C = C_i \frac{1}{1+W_f}\ [\%];\quad H = H_i \frac{1}{1+W_f}\ [\%];\quad O = O_i \frac{1}{1+W_f}\ [\%];\quad S = S_i \frac{1}{1+W_f}\ [\%];$$

$$N = N_i \frac{1}{1+W_f}\ [\%];\quad W = W \frac{W_i + 100W_f}{1+W_f}\ [\%];\quad A = A_i \frac{1}{1+W_f}\ [\%] \qquad (1)$$

The control of emulsified fuel combustion by means of the combustion diagram of liquid fuels

To determine the combustion imperfection of a fuel it is necessary to establish the excess-air coefficient [α] as well as the CO content in the burning gases. But the last value is determined with difficulty and so, it is better to determine the CO_2 and O_2 contents and to establish α and CO analytically and graphically it is introduced the simplifying hypothesis according to which the combustion process imperfection appears at the carbon combustion. The evidence is based on the following argument: the H_2 atoms have an average molecular velocity higher than that of carbon atoms, the number of collisions with the oxygen atoms is bigger and so the probability of carbon incomplete burning seems to be more likely. Supposing that "xC" burns in CO_2 and (1-x) C burns in CO, the consumed oxygen result from the relation:

$$O_C = O_{min} - \frac{1}{2}\cdot\frac{22{,}4}{12}\cdot(1-x)\cdot C = \frac{22{,}4}{12}\cdot C\cdot\left[\sigma - \frac{1}{2}\cdot(1-x)\right]\ [m^2\ N/kg], \qquad (2)$$

$$\sigma = 1 + 3\cdot\frac{H - \frac{O-S}{8}}{C}. \qquad (3)$$

The dry products of combustion when α>1 are given by the relations:

$$V_{CO_2} = \frac{22{,}4}{12}\cdot xC\ [m^3\ N/kg], \qquad (4)$$

$$V_{CO} = \frac{22{,}4}{12}\cdot(1-x)\cdot C\ [m^3\ N/kg], \qquad (5)$$

$$V_{O_2} = \lambda - O_{min} - O_C = \frac{22{,}41}{12}\cdot C\cdot\left[\sigma\cdot(\lambda-1) + \frac{1-x}{2}\right]\ [m^3\ N/kg], \qquad (6)$$

$$V_{N2} = \frac{0{,}79}{0{,}21}\cdot\frac{22{,}4}{12}\cdot\lambda\cdot C\cdot\sigma\ [m^3\ N/kg]. \qquad (7)$$

The volume of dry products is:

$$V_{gu} = \frac{22{,}4}{0{,}21}\cdot\frac{C}{0{,}21}\cdot\left[\sigma\cdot(\lambda-0{,}21) - 0{,}21\cdot\frac{3-x}{2}\right]\ [m^3\ N/kg]. \qquad (8)$$

By the formula of V_{gn} the shares of each element in the dry gas mixture can be determined. Due to the equality:

$$(CO_2)_f + (CO)_f + (O_2)_f + (N_2)_f = 1, \qquad (9)$$

The expression of $(N_2)_f$ can be neglected and under the hypothesis that CO_2 and O_2 are determined by analyzing the dry gases, a set of three equations with three unknowns, x, α, CO. By analyzing the relations of N_2:

$$\frac{(N_2)_f}{(CO_2)_f + (CO)_f} = \frac{0{,}79\cdot\lambda\cdot\sigma}{0{,}21}, \qquad (10)$$

- the value of excess-air is pointed out:

$$\alpha = \frac{0{,}21\cdot(N_2)_f}{0{,}79\cdot\sigma\cdot\left[(CO_2)_f + (CO)_f\right]}. \qquad (11)$$

- x is obtained from the ratio:

$$x = \frac{(CO_2)_f}{(CO_2)_f + (CO)_f} = \frac{0{,}21\cdot x}{0{,}21}. \qquad (12)$$

and substituting into the relations (12) we obtain:

$$(CO_2)_f + (CO)_f = \frac{0{,}21}{\sigma\cdot(\lambda-0{,}21) + 0{,}21\cdot\frac{3-x}{2}} \qquad (13)$$

The volumes of α and x, taking into account the relation (13), are obtain by:

$$(CO_2)_f \cdot (0{,}21+0{,}79\cdot\sigma)+(CO)_f \cdot \left[0{,}21+0{,}79\cdot\left(\sigma-\frac{1}{2}\right)\right]+(O_2)_f=0{,}21 \qquad (14)$$

The equation (14) is the equation of a plane, named the combustion plane. From the intersection of this plane with the perfect combustion plane $(CO)_f$ = 0, it results the line of perfect combustion with the following equations:

$$(CO_2)_f \cdot (0{,}21+0{,}79\cdot\sigma)+(O_2)_f=0{,}21. \qquad (15)$$

The perfect combustion line intersects the axes $(CO_2)_f$ and $(CO)_f$ in points A and B having the coordinates:

A de $\{(CO_2)_f=0;\ (CO_2)_{fmax}=\dfrac{0{,}21}{0{,}21+0{,}795}\}$;

and

B de $\{(O_2)_f=0;\ (O_2)_{fmax}=0{,}21\}$.

A point placed on AB line means a perfect combustion with an excess-air coefficient λ=1 and for this reason the CO_2 coefficient in smoke is minimal. If the combustion is imperfect, $(CO_2)_f \neq 0$ from the equation (12) , the maximum CO content from the burning gases is obtained in the origin of coordinate axes and its value is given by:

$$(CO)_{fmax}=\frac{0{,}21}{0{,}21+0{,}79\cdot\left(\sigma-\frac{1}{2}\right)} \qquad (18)$$

To plot the lines of $(CO)_f$ =ct., a line OD of arbitrary inclinations is drawn, so that the segment OD can be divided in as much equal parts as the value of $(CO)_{fmax}$ shows and, the lines parallel with the perfect combustion line are drawn through the division points so established. To determine the nature of curves α = ct. the following relations is analyzed:

$$\frac{(CO_2)_f+2}{(O_2)_f-1}=\frac{A+B\cdot\lambda}{C+D\cdot\lambda}, \qquad (19)$$

in which A, B, C, D represents the constants terms.
From the last relation it results that whatever its value is, all curves of α = ct. are concurrent lines in coordinate point $(CO_2)_f$ = 2 and $(O_2)_f$ = 1. The concurrent points being very far away, the lines α = ct. appear parallels in the diagram. To plot the lines, two points are established so:

- in the equations $(CO)_f$, x = 0 and α is a desired value determining the point of intersection with the axes of abscissae (x-axis).
- in the equations (10), x = 1 and α at the above value determining the point of intersection with the perfect combustion line. Alike, the other lines of α = ct. are drawn. The line α = ∞ passes trough the point B and physically it corresponds to a combustion with a very high excess-air. Knowing the value of the excess coefficient α = *optim*, and the analysis of combustion gases by means of the diagram, we can make the interpretation of combustion and draw conclusions regarding the fire control. A figurative (graphical) point of combustion has to be inside or on the outline (contour line) of the combustion triangle. Any point out of triangle represents an impossible composition of smoke from the physical point of view and it is a sign that the analysis of gases is incorrect (wrong).

THE ARDIAG PROGRAM

To determine the parameters of interest necessary for a comparison between the marine residual fuels, simple or emulsified, I conceived a program including all the stages mentions above and plotting the combustion diagram for a given gravimetric participation of fuel. The ARDIAG program determines the amount of CO and CO_2 in the combustion gases and the imperfect combustion point on the combustion diagram of liquid fuels for the initial input data. It is conceived and runs according to as logical diagram, in fig. 2. The program can determine the combustion characteristics both for water emulsified fuels and unemulsified ones, the results being at option.

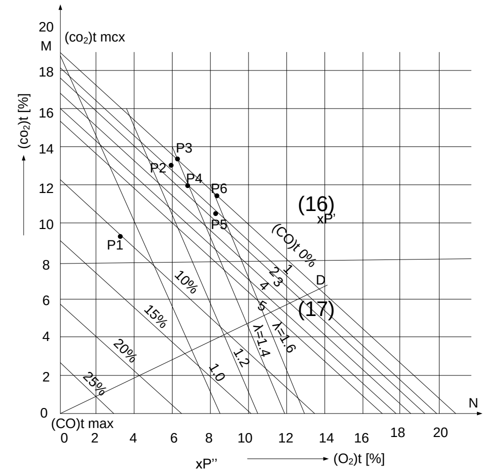

Fig.1. Combustion diagram determined for MRD 25 marine heavy fuel.

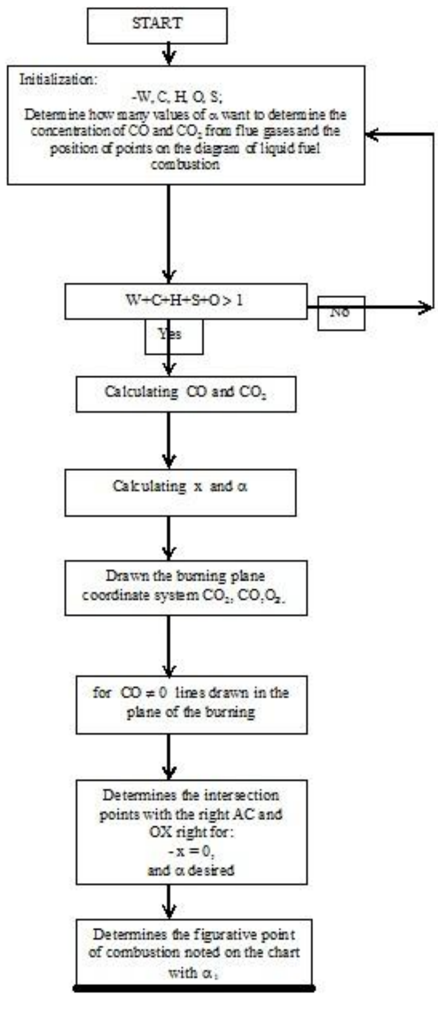

Fig. 2. *Flowchart of the ARDIAG program.*

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