

# THE COMBUSTION OSCILLOGRAMS OF WATER /HEAVY FUEL EMULSION DROPLET

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**Abstract:** The vaporization and combustion characteristics of a marine heavy oil-water emulsion droplet are investigated with graphological method. The combustion graphology of fuel oils is defined as a new technical and scientific field which deals with the graphic transposition of the processes of fuels combustion development in a simulator. Thus, it is easy to establish the ignition-combustion characteristics, including the laws that govern their changes depending on the combustion conditions and fuel specifications.

**Key words:** marine oil-water emulsion, vaporization, combustion, graphological method

## 1. INTRODUCTION

The combustion graphology of fuel oils is defined as a new technical and scientific field which deals with the graphic transposition of the processes of fuels combustion development in a simulator [Ghia, 1991]. Thus, it is easy to establish the ignition-combustion characteristics, including the laws that govern their changes depending on the combustion conditions and fuel specifications. The graphic representation of the combustion processes development for a droplet of liquid fuel used in the industrial combustion may be made by means of the so-called "combustion oscillogram" (fig. 1).

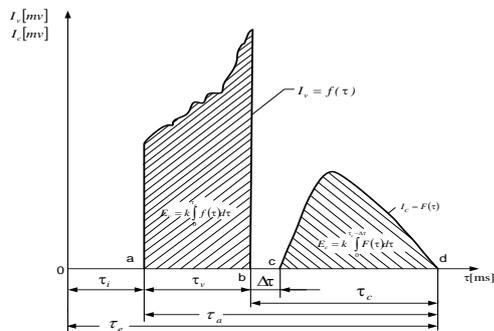


Fig. 1. Graphic representation of the combustion processes development for a heavy oil droplet

This graph specifies the time variation  $t$  of the light-thermal energy radiation intensity  $I$ , for a burning droplet, transformed into electric signals by means of an optical-electronically system, equipped with a photoelectrical cell [Jianu, 1996], [Popa & Iscrulescu 1983]. Thus for a marine heavy fuel oil this ignition and combustion graph establishes, in standard conditions the self-ignition delay  $\tau_i$ , the volatile matters combustion time  $\tau_v$ , the cenosphere combustion time  $\tau_c$ , the maximum radiation intensity obtained at the combustion of the cenosphere  $I_c^m$ , the maximum radiation intensity obtained at the combustion of the volatile matter  $I_v^m$ , the energy radiated by the burning cenosphere transformed by the photocell into electric energy  $E_c$ , etc. This paper deals with finding new methods and means for improving the combustion processes of marine liquid fuel. It tries to make evident the effects of water emulsion on

the marine liquid fuel during combustion. The assessment of emulsification influence was made by comparing the combustion performance and the results with those obtained in the absence of emulsification under the same test conditions [Jinescu, 1983]. The laboratory researches developed on the isolated droplet burning had in view to state the measure in which the emulsification would interfere for carrying on the secondary atomization [Law, 1997]. We also tried to determine the characteristics of induced flames following their configuration and radiation, and to assess the igniting and burning behavior of droplets by laying down comparison criteria of the following times:  $\tau_i$ ;  $\tau_v$ ;  $\tau_c$ ;  $\tau_a$ ;  $E_v$ ;  $I_v$ ;  $E_c$ ;  $I_c$ ; the simplex of temperature combustion  $S_{a_i}$ ; and the ignition ratio  $\psi$ .

## 2. THE WATER/HEAVY FUEL EMULSIONS COMBUSTION OSCILOGRAMS

I have made the combustion oscillograms for marine heavy fuel RMF25 with its characteristics mentioned in table 1, at which the water emulsification included four determination tests for water – marine fuel emulsion in proportions of 5[%], 10[%], 15[%] and 20[%]. At the combustion of water – marine fuel emulsion with a water percent of 40[%], the combustion becomes unstable.

In figures 2 and 3, there are synthetically presented the experimental results. Each point marked in diagrams represents the arithmetic mean of six determination tests.

CARACTERISTICA	RMF 25
Volumetric mass at 15[C], [kg/m <sup>3</sup> ], max.	991,0
Kinematic viscosity at la 100 <sup>0</sup> C, [mm <sup>2</sup> /s], max.	25,0
Ignition point [C], min.	60
Flow point in [C] - winter, max. -summer, max.	30 30
Coked residue, [%g/g], max.	20
Ash, % [g/g], max.	0,15
Water, % [v/v], max.	1,0
Sulphur, % [g/g], max.	5,0
Vanadium, [mg/kg], max.	500
Aluminium plus silicon, [mg/kg], max.	80
Existing total sediment, % [g/g], max.	0,10

Tab. 1. The characteristics of marine heavy fuel RMF25

Based on the data obtained it results that by emulsifying the RMF25 fuel with water from 0 to 20%, we obtain:  
 - the increase of self-ignition delay  $\tau_i$  from 525[ms] to

1170[ms];

- the decrease of lower heating power  $Q_i$ ;
- the maximum temperature variation  $T_f$  during the ignition processes;
- from the rate of curves  $\tau_v = f(w)$  and  $\tau_c = F(w)$  it results that in the emulsifying range 0 – 10[%] water the fastest decrease of times  $\tau_v$  and  $\tau_c$  appears; so it is recommended an average emulsifying value of 5 – 8[%];
- as the substitution of a fuel part for water reduces the combustion temperature once the vaporization of emulsified water needs an additional energy consumption, it is recommended that we should have an average value.

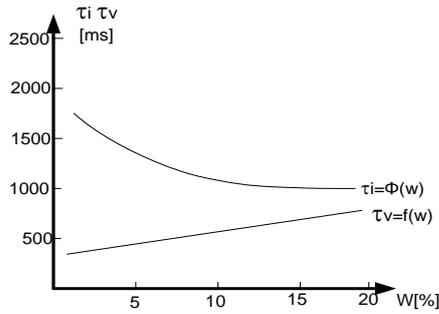


Fig. 2. The influence of water content in water – RMF25 marine heavy fuel emulsion on the quantities  $\tau_i$  and  $\tau_v$

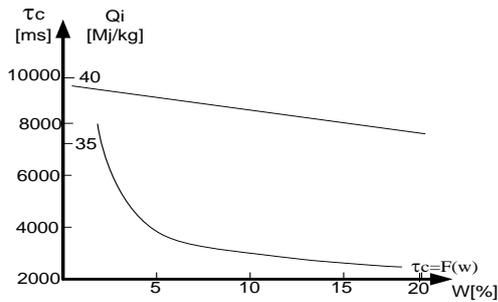


Fig. 3. The influence of water content in water RMF25 marine heavy fuel emulsion on the quantities  $Q_i$  and  $\tau_c$

The decrease velocities of times  $\tau_v$  and  $\tau_c$ , respectively, that is the ratios  $d\tau_v/dw$  and  $d\tau_c/dw$  depend on the characteristic of emulsifying system used, namely, the smaller diameter of water drops in the resulted emulsion and more homogeneous distributed, the more sudden the decrease of times; as a result, for the same effect of reducing the nitrogen oxide generation, it will be necessary a smaller percentage of water for emulsification. For a systematical differentiation of fuels, from the three points of interest, namely, of ignition, of combustion and of luminous drop energy, the following specific indices and global quality indices of combustion have been defined:

- the expression of combustion quality  $S_a$  (its value is reduced according to the damage of fuel quality);

$$S_a = \frac{\tau_c}{\tau_v} \quad (1)$$

To state the weight of ignition process to the combustion processes of volatile matters and cenosphere, the ignition ratio  $\psi$  has been defined, increasing with the rise of  $\tau_i$  value:

$$\Psi = \frac{\tau_i}{\tau_i + \tau_v + \tau_c} \quad (2)$$

The weight of the energy radiated by burning the volatile matters  $E_v$  to the total energy  $E_v + E_c$  has been stated by the

radiation index (ratio)  $B$ , of which the value decreases with the damage of fuel quality:

$$B = \frac{E_v}{E_v + E_c} \quad (3)$$

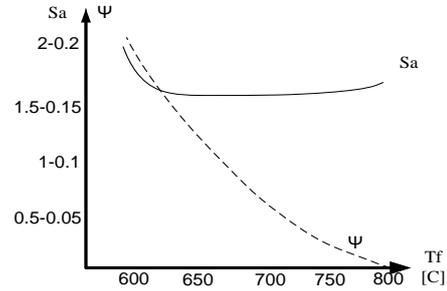


Fig.4. The variation according to the temperature of combustion simplex  $S_a$  and ignition ratio  $\psi$

The global combustion quality index  $G = f(A,0)$  decreases by damaging the composition of heavy liquid fuels:

$$G = C \frac{\tau_v}{\tau_i + \tau_c} \quad (4)$$

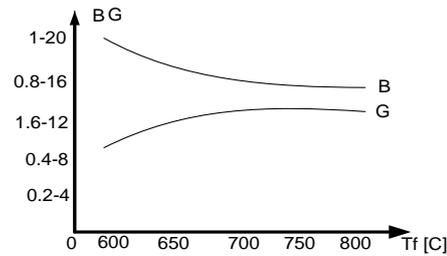


Fig. 5. Variation of  $B$  and  $G$  indices depending on the temperature  $T_f$

### 3. CONCLUSIONS

The test results of the isolated water/heavy fuel emulsion droplet burning presented, lead to the following conclusions:

- the increase of  $S_a$  value together with the increase of cenosphere content of fuel;
- the decrease of ignition index  $\psi$  by increasing the temperature  $T_f$ ;
- the ignition index (ratio)  $\psi$ , increases with the rise of  $\tau_i$  value;
- the decrease of radiation index  $B$ , by damaging the content in cenosphere of fuel.

The introduction of water into the combustion chamber reduces the combustion temperature due to the absorption of energy for vaporization. Thus, the humidification can reduce the  $NO_x$  emissions.

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