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COMBUSTION CONTROL OF SOLID, LIQUID AND GASEOUS FUELS

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Abstract: *The heat has a leading role in economic and social life. Mostly it is produced by combustion of classic fuels (such as liquid fuels, solid and gaseous), non-renewable, thus it is required a special attention in order to produce and use it more efficiently. For a long time, construction of combustion devices and especially the burners was dominated by a total empiricism, caused by insufficient knowledge of the complex processes that occur during formation of fuel mixture, ignition and deployment of oxidation reactions within heat exchanger made in the burning furnace (oven).*

Key words: *burners, heat, furnace, combustion control*

1. CONSTRUCTIVE AND FUNCTION PRINCIPLES OF BURNERS

In the combustion plant, the burner has the role of inducing into furnace (in a dynamic gaseous configuration well defined) the fuel and combustion air. From a technical standpoint the burner must meet the following requests [1]:

- To achieve dynamic gaseous conditions for a stable combustion in the field charge where the combustion installation operates and for the whole range of fuel quality;
- Toxic and corrosive products (such as NO_2, SO_2, CO ...) must not exceed the allowable limits;
- Losses by non-combustion from mechanical and chemical point of view, must not depart from the optimal values;
- The fields of temperature, velocity and concentration must have a conformation that does not produce inadmissible overheating (e.g. clay deposits, …);
- Aerodynamic resistance of the burner must not be extremely high, to limit energy consumption;
- The burner must operate at a low noise level and must not produce resonance with furnace;
- In operation, the temperature regime should be so that it does not cause damage or deterioration to the burner;
- Repair and maintenance costs must be reduced;
- Adjusting the combustion process to be as simple as possible;

In the event of turbulent flames, fuel ignition stability is provided by the ratio of the recirculated exhaust gas heat of the flame, by the effect of the driving jets produced by the burner.

Thus, there can be distinguished [2]:

- non swirl jets burners, where the recirculation is external (exterior stabilization);
- swirl jet burner, where recirculation is both external and internal (internal stabilization).

From this perspective, swirl burners have the advantage of superior stability parameters due to the greater amount of recirculated gases. They are recommended especially for fuels which are difficult to ignite: solid fuels with high content of ballast or low volatile matter content, poor gas fuels; they are also recommended for small and powerful furnaces where external recirculation receives low temperatures.

In case of swirl burners, fuel should be introduced into the furnace, between the forward flow of secondary air and back of the internal recirculated gas, where speed is practically null and proper condition are created for ignition.

Internal recirculation is obtained by the following tools [3]:

1. Placing non-aerodynamic bodies that create behind them reverse circulation area;
2. Devices swirl of primary and secondary air;
3. Conical aperture.

Swirl burners actually use a combination of these constructive tools. Operating parameters can be influenced by:

- Constructive solutions, the degree of swirl size, length and angle of aperture, the aerodynamic body shape.
- The size and rate ratio of primary and secondary air insufflation.
- Therefore, there can be obtained many forms of internal recirculation: closed, open or ring. Selecting the most appropriate parameters for operation is done according to the characteristics of the fuel and the furnace.

2. COMBUSTION CONTROL

Burning is a physical-chemical process, extremely complex, depending on the conditions under which it is performed, the nature of the fuel, heat consumer characteristics and other factors, therefore, it is practically impossible a perfect combustion. The extent to which combustion is close to perfection, is determined by controlling the combustion. This operation is made by experimental determination of the composition of the combustion gases and by analytical determination or graphic of the coefficient of the air excess. One of the final results of the combustion control is to determine combustion efficiency.

Based on findings, measures may be established to improve or optimize the combustion process. For example, absence of carbon and carbon monoxide in the flue gas denotes a perfect combustion, but the presences of these elements indicate imperfections. The presences of combustible components in the flue gas, even at a reduced scale, indicate an imperfect combustion from chemical point of view. Experimentally, it has been found that modification of excess air, for example, can improve the combustion process.

Flue gas composition is verified experimentally by sampling fumes. On the pipe connecting the outlet of fume sampling and the device performing a chemical analysis of composition, called *gas analyser*, along with gas cooling occurs the condensation of water vapour contained in these gases. For this reason, it is actually carried out the *analysis of dry flue gas composition*; therefore in calculation relations to each chemical element the index „u" will be associated.

3. ANALYTICAL – EXPERIMENTAL CONTROL

This burning control method aims to determine experimentally the combustion flue gas composition and based on it, the analytical calculation of the coefficient of excess air.

In principle, it is considered a volume V_g^u of dry, known flue gas. Partial volumes of components, therefore satisfying relationship. In principle, considering a volume V wet and dry flue gas known. Partial volumes of components, basically meet the relation:

$$V_{CO_{2u}} + V_{O_{2u}} + V_{CO_u} + V_{N_{2u}} + V_{SO_{2u}} = V_g^u \tag{1}$$

By definition, $\lambda = \frac{L}{L_{min}}$ where the form can be obtained:

$$\lambda = \frac{L}{L - L_{ex}} \tag{2}$$

Where λ is Darcy load

is the amount of air that participated in the combustion process

is the excess air.

The amount of air that participated in the combustion process can be determined, neglecting the nitrogen content of fuel, knowing the volume share of nitrogen in air (79%) through [4]:

(3)

If there is oxygen in the combustion gases, this can be explained either by incomplete combustion of the carbon, in which case there is carbon monoxide (CO), or by the presence of excess air. Therefore, knowing the density of the oxygen participation in the air, the excess air can be determined using the relations:

(4)

Replacing in the definition relation, the excess air becomes:

(5)

Equivalent to:

(6)

If this relation is divided to volume of combustion dry gas analysed, it is obtained the relation to calculate the excess air according to the volume share, experimentally obtained by analysing the chemical composition of the combustion gases in the form of [5].

(7)

Where:

2 (8)

Is nitrogen volume participation.

4. GRAPHIC-EXPERIMENTAL CONTROL

The graphic-experimental control of combustion means the experimental setting burning gas composition, followed by graphic determination of the coefficient of excess air.

For each type of fuel it was traced a diagram which allows to set, using the graph, a link between the chemical composition of flue gases and excess air corresponding to that composition. This diagram is called *combustion triangle or Ostwald diagram,* and has its structure presented in figure 1.

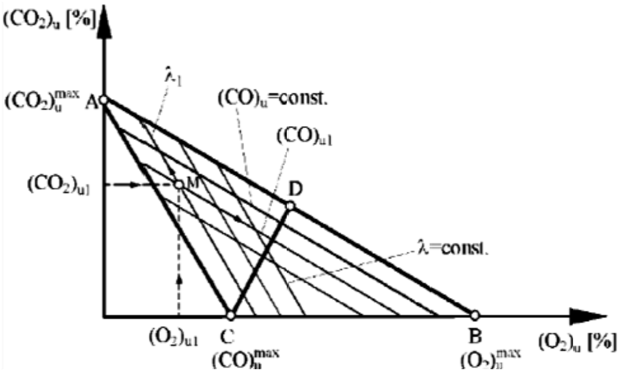

Fig. 1 Combustion triangle. [6]

Any combustion process is characterized by a point on the combustion triangle. The points marked on the figure have the following meaning:

- A corresponds to complete combustion, stoichiometric (= 1);
- B corresponding to complete combustion with infinite excess air (λ = ∞);
- C is the concentration of oxygen in the flue gases for an incomplete combustion, where $(CO_2) = 0$, and (CO) = maximum;
- D is the intersection between the line AB and high perpendicular of C, on AB.

The right AB is the geometric place of points corresponding to complete combustion, with different values of excess air (λ). Following flue gas composition analysis, a point that defines the process of combustion is obtained, and that point must lie inside the combustion triangle or at limit on the right AB. If the point is outside the triangle, then the experimental measurements are flawed.

The parallel rights to AB are straight lines with concentration of CO constant, and this concentration increases from D (CO) = 0 to C (CO) = (CO) max. Parallel lines to AC are straight with excess air (λ) constant, the size increases from point A (λ = 1) to point B (λ = ∞).

Coordinates of all the characteristic points of the combustion triangle can be calculated, or determined graphically.

Point A has the ordinate:

$$y_A = \frac{V_{CO_2}^{max}}{V_g^u} 100, [\%] \qquad (9)$$

where $V_{CO_2}^{max}$ is CO_2 volume at complete combustion.

In the case of solid and liquid fuels, the amount of carbon dioxide can be calculated from the relationship [7]:

$$V_{CO_2}^{max} = 1.867c, \left[\frac{m_N^3}{kg}\right] \qquad (10)$$

And the volume of dry flue gas, by:

$$V_g^u = V_{CO_2} + V_{N_2} + V_{SO_2}, \left[\frac{m_N^3}{kg}\right] \qquad (11)$$

Where $V_{NO_2} = 0.7s$;

$$V_{N_2} = 0.79\, L_{min} \qquad (12)$$

For gaseous fuels, the amount of carbon dioxide can be calculated from the relationship:

$$V_{CO_2}^{max} = (CO) + \sum m\,(c_m h_n) + (CO_2), \left[\frac{m_N^3}{m_N^3}\right] \qquad (13)$$

And the volume of dry flue gas, by:

$$V_g^u = V_{CO_2} + V_{N_2} + (n_2), \left[\frac{m_N^3}{kg}\right] \qquad (14)$$

Point B, as it corresponds to excess air (λ = ∞), has abscissa:

$$x_B = (O_2)_u = 0.21\,\% \qquad (15)$$

Point C is determined by (λ = 1), at incomplete combustion resulting only CO, by the abscissa:

$$x_C = (O_2)_u^{CO} = \frac{V_{O_2}}{V_g^{CO}} \cdot 100,\ [\%] \qquad (16)$$

In case of solid and liquid fuels:

$$V_{O_2}^{CO} = 0.21\left(L_{min} - \frac{1}{0.21}\,\frac{22.414}{2.12}\,c\right), \left[\frac{m_N^3}{kg}\right] \qquad (17)$$

And

$$V_g^{CO} = 1.867c + 0.7s + 0.79L_{min}, \left[\frac{m_N^3}{kg}\right] \qquad (18)$$

In case of gaseous fuels:

$$V_{O_2}^{CO} = 0.21\Big(L_{min} - \frac{1}{0.21}\sum\frac{m}{2} +$$

n4cmhn, *mN3mN3* (19)

And

$$V_g^{CO} = \sum m\,(c_m h_n) + (CO) + (CO_2) + 0.79L_{min}, \left[\frac{m_N^3}{m_N^3}\right] \qquad (20)$$

Point D, is obtained by the graphic construction described above.

Usually flue gas composition analysis determines the participation of oxygen, for example and carbon dioxide$(CO_2)_{u1}$.Then, point M is set on the combustion triangle having as coordinates these sizes and it is determine graphically the participation of carbon monoxide $(CO)_{u1}$, respectively excess air λ_1. Knowing the position of the combustion characteristic point, can be set the direction where has to be intervened to decrease the concentration of (CO), by providing a value λ, which ensures a desired temperature of combustion.

Also, if it is determined experimentally the (CO) as well, it can be verified how accurate the measurements are, so that $(CO)_{u1}$, determined graphically should be approximately equal to the $(CO)_{u1}$, established experimentally.

5. CONCLUSIONS

The combustion process is a physical-chemical interaction between fuel and air in the atmosphere. As a result, improvement of technical characteristics and performance of combustion installations involve mastering the complex interaction of physical and chemical processes that occur in flames, as the physical processes similar to those for energy transfer, mass and impulse play along with reaction speed an important role.

For turbulent flames an important role has the turbulent diffusion, a process that is closely related to the flow conditions from flame and furnace. Therefore, differences between combustion installations with limited burning volume to those with infinite volume (high volume) may occur.

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CONTROLUL ARDERII COMBUSTIBILULUI SOLID, LICHID SI GAZOS

Rezumat: Orice substanța care reacționează cu oxigenul din aer si produce căldura utilizabila avantajos din punct de vedere tehnico-economic se numește combustibil. Combustibilii se folosesc in aproape toate procesele industriale si in special in producția de energie electrica. Combustibilii folosiți pentru producerea energiei se numesc combustibili energetici. In funcție de starea de

agregare, acestea sunt: combustibili solizi, combustibili lichizi si combustibili gazoşi. Combustibilii solizi si lichizi se caracterizează prin compoziţia elementara exprimata in procente de masa, iar combustibilii gazoşi se caracterizează prin compoziţia volumetrica exprimata in procente de volum.

In proiectare, considerând procesul de ardere ca un proces de reacţie intre componentele combustibile ale combustibilului si oxigenul din aer atmosferic in instalaţiile de ardere, este necesara determinarea prin calcul al cantităţilor de aer necesar arderii si de gaze de ardere rezultate in cadrul arderii complete.

In construcţia arzătoarelor un caz special îl reprezintă acele arzătoare care realizează o flacăra scurta posibile de utilizat in incinte cat mai reduse. Acest deziderat îl realizează flăcările turbionate, un jet turbionat fiind caracterizat prin o lăţire a sa, concomitent cu o puternica reducere a lungimii (penetraţiei).

Utilizarea unor combustibili cu o capacitate redusa de aprindere, precum si a unora de calitate inferioara, a condus de asemenea la folosirea unor tehnologii de ardere in jeturi rotationale, curentul de recirculaţie din centrul acestora, compus din gaze calde din zona finala a flacarii jucând rolul de stabilizator termic.

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