CALCULUL NECESARULUI DE AER DE COMBUSTIE LA CUPTORUL DE CLINCHER ÎN CAZUL UTILIZĂRII LA ARDERE A COMBUSTIBILILOR PRIMARI ŞI ALTERNATIVI

CALCULATION OF THE COMBUSTION AIR NEEDED FOR THE CLINKER KILN IN CASE OF USING PRIMARY AND ALTERNATIVE FUELS FOR BURNING

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The usage of fuels in cement industry has achieved significant thresholds, currently is seeking solutions for the optimization of fuel mix necessary for a good kiln operations. The study presents the combustion air needed for a fuel mix (conventional and alternative fuels) in different percentages as well as their influence on production and consumption in cement plants.

Utilizarea combustibililor alternativi în industria cimentului a atins praguri semnificative, în prezent căutându-se soluţii pentru optimizarea amestecului de combustibili în vederea unei bune operări a cuptorului. Lucrarea prezintă determinarea necesarului de aer de combustie în cazul utilizării la ardere a unui amestec de combustibili (convenţionali şi alternativi) în diferite proporţii precum şi influenţa utilizării acestora asupra producţiei şi consumurilor în fabricile de ciment.

Keywords: *clinker kiln, alternative fuels, fuel specific consumption, process parameters, combustion*

1. Introduction

Cement manufacturing is an energy-intensive process due to the high temperatures required in the kilns for clinkering. Depending on the process, cement production typically requires 3.2-5.0 MJ/kg clinker of thermal energy [1]. The energy is supplied to the process through combustion of different types of fuel [2].

Clinker burning still remains a very complex process in terms of chemical and thermal processes occurring within the cement plant [3]. Combustion is defined as a chain of chemical reactions between fuel and oxygen, at a temperature high enough to obtain heat and combustion products. Fuel can be gaseous, liquid or solid. Combustion rate can range from a slow one to a rapid one. The chemistry of the combustion process includes a complex series of chain reactions. The main reactions at the base of combustion process are [4]:

$C + O_2 \rightarrow CO_2 + 394$ kJ/mol

$2H_2 + O_2 \rightarrow 2\,H_2O$ + 572 kJ/mol – condenser water (GCV)

+ 484 kJ/mol – steam (NCV)

$2C + O_2 \rightarrow 2CO + 221$ kJ/mol

The main thermal effect of carbon monoxide forming is decreasing the heat released through fuel combustion. In the case of carbon monoxide generation, the amount of generated heat represents more than half of the one released through complete combustion. Thus, the burner that produces carbon monoxide as a result of inappropriate fuel/air mixing will determine significant decrease of burning efficiency.

Oxidation of carbon monoxide:

$2CO + O_2 \leftrightarrow 2CO_2 + 173$ kJ/mol

From quality point of view, efficiency of combustion process is determined by the ratio value and by the homogeneity of fuel/air mixture. Insufficient homogeneity of fuel/air mixture determines CO occurrence in combustion gases and has as effect decreasing the potential energy of the fuel. For a complete combustion, it is necessary to provide at least the amount of theoretical air required for burning and a good homogeneity of the fuel and air mixture. The primary air has two important roles:

-ensures the combustion initiation and influences the fuel/air ratio;

-ensures the flame stability.

Primary air blends rapidly with fuel in the burner's nozzle, and secondary air is carried in the primary air and fuel mixture. The higher the flow

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and rate of primary air are, the more rapid the blending of fuel with air is. The carrying rate of secondary air is depending on the ratio of fuel/primary air mixture and secondary air flows. The flame properties are determined by this flow ratio.

Air from combustion gases at the exit from preheater/id fans entrance comes from excess air and from air infiltrations in the kiln area and in the preheater area. These infiltrations can be determined through oxygen measurements at the kiln backend and in different points in the preheater.

In the installation, the false air determines the decrease of the hot gases temperature and, therefore, the decrease of the processed material flow [5]. These infiltrations are a measure of the installation sealing level and have a negative effect on the kiln performances (specific production and consumption).

Increasing the oxygen concentration at kiln backend from 1% to 5% determines the increase of kiln heat consumption with nearly 10%. A low level of oxygen in the flame generates the occurrence of carbon monoxide in combustion gases. This leads to an increase of fuel consumption because of carbon incomplete combustion. The more homogeneous the fuel/air mixture is, the lower the level of excess air at which CO emissions occur is. The environmental impacts of toxic gases (CO, NO_X) or greenhouse gases (CO_2) discharged into the atmosphere from the clinkering plant should be carefully monitored [6].

2. Calculation hypotheses

For assessing the flows of combustion air and combustion gases in different points of the clinkering installation (kiln backend, preheater exit and id fans entrance), the following information and calculation conditions have been used:

-process information, collected for a reference period of clinker kiln activity (24h);

-analyses of primary fuels and combustible wastes used at burning in clinker kilns;

-recipes of primary and alternative fuels used/foreseen to be used at burning in clinker kilns;

-the main project features of id fans (flow, temperature, static pressure, etc);

-production and specific consumptions of heat / presumed at clinker kilns.

For the clinker installation plant to which the combustion air was calculated, the following were considered:

-primary air and false air flows at the kiln hood for a reference period of clinker kilns activity;

-combustion gases flow in different points of clinkering installation (kiln backend, preheater exit, id fans entrance) calculated at normal conditions;

-id fans flow brought at normal conditions (maximum flow = 234,682 Nm^3/h);

-O_2 concentration at the kiln backend ranging between 0.5% and 2.0%;

-clinker kiln production ranging between 3,000 and 3,500 t/day;

-specific consumption heat for kiln ranging between 3.14GJ/t cl and 3.56GJ/t cl

Three fuel recipes were taken into calculation. The three fuel recipes taken into consideration and expressed as thermo-energetic proportions are:

-recipe I, 88% coal, 10% used tires, 2% natural gas);

-recipe II, 90% coal, 10% used tires);

-recipe III, 67% coal, 8% used tires, 25% SSW (shredded solid wastes) [7].

For each fuel recipe, the following combustion air/combustion gases properties were calculated:

-theoretic flow of air necessary for burning in stoichiometric conditions;

-flow/theoretic composition of burning gases (dry gases – resulting from combustion / wet gases – the combustion gases includes the humidity of raw materials, fuels and air [8]) resulted in stoichiometric burning conditions;

-flow/composition of combustion gases resulted through decarbonation of the flour and burning its components ($C_{organic}$, $S_{sulfides}$);

-flow/composition of combustion gases (dry/wet) at kiln backend;

-excess air flow at kiln backend;

-flow/composition of combustion gases (dry/wet) at preheater exit;

-flow/composition of combustion gases (dry/wet) at id fans entrance;

-false air flows between kiln backend-preheater exit-id fans entrance;

-id fan stock (resulting from the difference between the nominal flow and the flow measured in the installation).

3. Results and discussions

The variations of combustion air/combustion gases specific flows, in conditions of stoichiometric combustion (C_s=3.14GJ/t cl), is presented in Table 1.

Changing the fuels recipes does not bring significant changes in combustion air/combustion gases flows. Results of air/combustion gases flows calculated in the three points of the clinkering installation (kiln backend, preheater exit, id fans entrance), for the three fuels recipes, the four O_2 levels at kiln backend, at clinker productions and presumed thermal consumptions, are presented in Table 2 (for a production of 3,250 t cl/day and a specific heat consumption of 3.35 GJ/t cl.)

It can be observed that:

-minor variations of gases flows in the three points of the clinkering installation for recipes I, II and slightly increased for recipe III;

Table 1

Specific flows variation of combustion air/gases. / *Variaţia debitelor specifice de aer de combustie/gaze de ardere.*

Recipe *Reţeta*	Specific gas flow- combustion under stoichiometric conditions, Nm^3/t cl *Debite specifice-combustie stoichiometrică, Nm^3/t cl*		
	Air / *Aer*	Dry gases / *Gaze uscate*	Wet gases / *Gaze umede*
I	823	794	856
II	822	794	853
III	830	798	864

Table 2

Variation of air / flue gas flows. / *Variația debitelor de aer/gaze de ardere*

Recipe *Reţeta*	Kiln backend O_2 level, % *O_2 cap rece, %*	Kiln backend gas flow, Nm^3/h *Debit gaze ardere cap rece, Nm^3/h*	Preheater exit gas flow, Nm^3/h *Debit gaze ardere ieşire schimbător, Nm^3/h*	Id fan entrance gases flow, Nm^3/h *Debit gaze ardere ventilatoare, Nm^3/h*	Secondary air flow, Nm^3/kg cl *Debit aer secundar, Nm^3/kg cl*	ID fans stock, % *Rezervă ventilatoare, %*
I	0.5	133.590	192.578	197.055	0.710	15.3
	1.1	137.443	196.431	200.908	0.739	13.6
	1.5	140.144	199.132	203.609	0.758	12.5
	2.0	143.680	202.668	207.145	0.785	10.9
II	0.5	133.149	192.137	196.614	0.709	15.5
	1.1	137.002	195.990	200.467	0.737	13.8
	1.5	139.702	198.691	203.168	0.757	12.6
	2.0	143.239	202.227	206.704	0.783	11.1
III	0.5	137.358	193.782	198.273	0.735	14.7
	1.1	141.297	197.721	202.213	0.764	13.1
	1.5	144.059	200.482	204.973	0.785	11.9
	2.0	147.674	204.097	208.589	0.812	10.3

Table 3

ID fans stock variation / *Variația rezervei ventilatoarelor de exhaustare*

Recipe *Reţeta*	Kiln backend O_2 level, % *O_2 cap rece, %*	Kiln production, t cl/day *Producţie, t cl/zi*	Fuel specific consumption, GJ/t cl *Consum specific de combustibil, GJ/t cl*	ID fans stock, % *Rezervă ventilatoare,%*
I, II, II	0.5	3.000-3.500	3.14	>10
		3.000-3.250	3.35	
		3.000-3.250	3.56	
		3.500	3.35	<10
		3.500	3.56	
I, II, III	1.1	3.000-3.500	3.14	>10
		3.000-3.250	3.35	
		3.000	3.56	
		3.500	3.35	<10
		3.250-3.500	3.56	
I, II, III	1.5	3.000-3.500	3.14	>10
		3.000-3.250	3.35	
		3.000	3.56	
		3.500	3.35	<10
		3.250-3.500	3.56	
	2.0	3.000-3.250	3.14	>10
		3.000-3.250	3.35	
		3.000	3.56	
		3.500	3.35	<10
		3.250-3.500	3.56	

Table 4

Composition of combustion gases. / *Compoziţia gazelor de ardere.*

Recipe *Reţetă*	Kiln backend O_2 level, % *O_2 cap rece, %*	Preheater exit gas analyses, % / *Compoziţie gaze de ardere ieșire schimbător, %*		
		CO_2	N_2	H_2O
I	0.5	32.78	58.58	5.31
	1.1	32.14	58.94	5.23
	1.5	31.71	59.19	5.17
	2.0	31.16	59.50	5.10
II	0.5	32.94	58.62	5.10
	1.0	32.30	58.98	5.02
	1.5	30.22	60.56	5.27
	2.0	31.31	59.54	4.90
III	0.5	32.48	58.59	5.62
	1.0	31.83	58.96	5.53
	1.5	31.40	59.21	5.47
	2.0	30.85	59.52	5.39

-increasing of O_2 content in combustion gases at the kiln backend leads to the increase of secondary air flow and decreasing of the stock of id fans;

-combustion gases flow and secondary air flow ranges directly proportional with clinker production and with the thermal consumption of the kiln.

For the operation without problems of the kiln it was considered that the flow stock at the ID fans to be a minimum 10%. Falling within this condition for all the operation options taken into consideration is done as follows:

Over 60% of the total options taken into calculation have the stocks of id fans higher than 10%, as shown in Table 3.

In Table 4 it is presented the composition of gases at preheater exit, function of the above-mentioned variables.

A slight decrease in the content of CO_2 from the combustion gases can be observed through increasing the O_2 content at the kiln backend, following the increase of specific secondary air flow.

4. Conclusions

The paper presents the calculation of the combustion air needed for burning a mixture of fuels (conventional and alternative) in different proportions as well as the influence of their use on the production and consumption in the cement plants.

The calculation performed for the combustion air needed for the clinkering installation showed an increase in the content of oxygen at the kiln backend, leading to a decrease in id fans flow stock due to the increased secondary air flow. There is also a linear increase in combustion gases flow and of the secondary air flow together with increased of clinker production and of clinker kiln's heat consumption. Therefore, the id fans flow stock varies inversely proportional with clinker production and kiln's heat consumption.

The influence of changing the fuel recipe on the combustion air/combustion gases flows is very small.

About 63% of the total options taken into calculation have the id fans stocks bigger than 10%.

These correspond to productions of 3,000-3,500 t cl/day and specific heat consumption of 3.14 GJ/t cl, respectively 3,000-3,250 t cl/day and specific heat consumption of 3.35 GJ/t cl.

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