RESEARCH CONCERNING THE DESIGN OF MEDIUM THERMAL POWER BOILERS FOR BIOMASS COMBUSTION IN SUSPENSION

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Combustion of sawdust and straw as compacted biomass (pellets or briquettes) does not lead to positive results for thermal power plants having over 100 kW. As a result, nowadays, experiments are carried out in order to implement the technology of combustion in suspension. This combustion technology allows greater charge at the same volume and flexibility at partial loads. Several experiments have been conducted for straw energetic recovery in a 100 kW boiler using the technology of combustion in suspension.

Keywords: combustion, sawdust, briquette, boilers.

1. Introduction

Sawdust combustion is usually in the form of briquettes or pellets. By compression is raising the density, especially for an easier supply and greater charge in the volume of combustion zone to the limits achieved to coal combustion on the grate. Combustion technology in suspension, aims to increase the thermal power of furnace volume, by continuous feeding and an increased combustion rate.

3. Briquette Sawdust combustion

Figure 1 shows a composite briquette of coal and sawdust, size of 46/34 mm and weight 50 ± 2 g.

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Fig. 1. Composite briquette

Fig.2. The flame in the 55 kW boiler furnace

The composite briquettes have been made by cold pressing of a mixture containing hard coal dust (60%), corn shreds (20%), sugar treacle (15%), limestone (5%), with LCV of 13900 kJ/kg. Limestone is added in order to capture SO2 and prevent the air pollution.

In table 1 are presented the results of experimental tests.

Table 1.

Experimental results of composite briquettes combustion

Nr. crt.	Characteristic	Test			
		1	2	3	4
1	Thermal load, [kW]	48	48	49	49
2	Fuel flow-rate, [kg/h]	16,8	16,9	17,1	17
3	Stack temperature (t_{ev}), [0C]	160	161	164	162

4	CO_2 emission, [%]	3,9	4,0	3,8	3,9
5	SO_2 emission, [ppm]	70	72	72	70
6	NO_x (NO+NO2) emission, [ppm]	42	42	41	42
7	CO emission, [%]	0,14	0,15	0,18	0,17
8	Air excess coefficient in stack, λ stack	3,4	3,4	3,37	3,4
9	O_2 at stack, [%]	14,2	14,64	14,4	14,5
10	Boiler efficiency (gas analyzer), [%]	76,4	76,9	77,4	78,2
11	Boiler efficiency (indirect method), [%]	64,2	64,6	65,3	65.8

When calculate the boiler efficiency by indirect method it should take into account also the heat losses in slag and flying ash. The most important factor that influences the overall efficiency is the air excess coefficient. If it is possible to ad a control system to the air admission and decrease the air excess coefficient to $\lambda_{ev} = 2{,}7 - 2{,}8$, efficiency would increase to $\eta = 72 - 77$ %.

3. Sawdust combustion with pulverized technology

To define a complex module to burn solid fuel particles with pulverized technology we start with the following equation, considering:

- temperature variation in fuel-air mixture:

$$a\frac{dT}{dx^2} - u\frac{dT}{dx} + q = 0 \tag{1}$$

where: $a = \frac{\lambda}{\rho \cdot c_p}$ is thermal diffusivity of the air-fuel mixture; x is the flow coordinate; q is quantity of heat reaction, u is normal velocity of flame front (quantity of fuel that burns per area unit in time unit).

- concentration variation c, of reactant substances:

$$D\frac{d^2c}{dx^2} - u\frac{dc}{dx} - \frac{1}{\rho}K_0 e^{-\frac{E}{RT}} = 0 \tag{2}$$

where: K_0 - constant of reaction rate, E - activation energy, R – constant of perfect gas

For maximum length of flame, the following relationship results:

$$l_{\max} = \frac{3\rho_c u}{C_0 K' F}\Phi(\mu_0, \varepsilon), \tag{3}$$

where: ρ_c is the apparent density of the fuel; C_0 - initial concentration of fuel-air mixture; K' - burning rate overall constant.

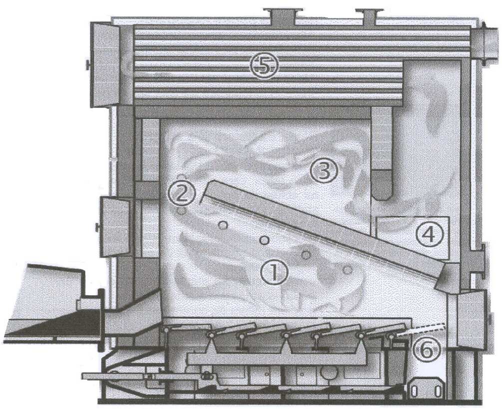
$$\frac{1}{K'} = \frac{1}{K} + \frac{\vartheta r_0}{D} + \frac{\vartheta^2 r_0}{\varepsilon D} \tag{4}$$

As r_0 it was noted as initial radius of the particle fuel, Q is the dimensionless radius $\vartheta = r/r_0$, ε - is ratio of outer and inner surface of the particle fuel; $\left(\varepsilon = \frac{3}{r_0 F}\right)$; F - inner surface of pores per volume unit of particle; $\Phi(\mu_0, \varepsilon)$ is a function of initial mass concentration of fuel μ_0 and coefficient ε.

For a certain degree of combustion, the length of the combustion path is defined by the equation:

$$d_x = \frac{3\rho c u d\vartheta}{K'F(Q+\varepsilon)\left[c_0 + \frac{\mu_0 c_0}{M}\left(\varphi^3 - 1\right)\right]M} \tag{5}$$

where: $M = \mu\alpha_{0_2}$, α_{0_2} - the excess of oxygen coefficient;



1-furnace; 2-return area; 3-post-combustion chamber;
4- end of burning space; 5-smoke pipes; 6- slag exhaust.

Fig. 3. Cross-section trough the boiler

Figure 3 presents the design concept of the boilers with an average thermal power of about 70 kW - 1.5MW. These boilers can use the combustion technology on mobile grate for briquettes or fluidized bed combustion technology for sawdust.

Sawdust suspension is obtained by means of the air flow rate introduced in a chamber that covers the grate.

High combustion rate leads to a concentration of flame in the area of fluidization air insufflations.

Secondary and tertiary air insufflated at the end of the combustion chamber 1 and in the post combustion chamber contributes to CO and NOx reduction.

4. Experimental results

Experimental combustion of sawdust with elemental analysis:
C^i = 42,1 %, H^i = 5,5 %, N^i = 0,7 %, O^i = 33,4 %, W_t^i = 13,27%, A^i = 5,03 %, LCV = 16 800 kJ/kg, by fluidization at the grate level leads to the following results:

- boiler efficiency , $\eta = 75 - 77\,\%$;
- air excess coefficient at the stack, $\lambda_{ev} = 3{,}9 - 4{,}5$;
- flue gases temperature at the stack, $t_{ev} = 150 - 165^0 C$;
- nitrogen oxide emissions , $NO_x = 40 - 60$ ppm for $O_2 = 7\%$;
- thermal charge in furnace volume: 450 - 480 kW/m^3

Figure 4 presents the aspect of combustion in a boiler of 80 kW thermal power.

Fig. 4. The flame in the 80 kW boiler furnace

For thermal power over 2 MW, is recommended the sawdust combustion technology in suspension by insufflations in swirl burners, similar those for pulverized coal.

For design data is recommended:

- primary air / total air combustion ratio: a_p = 0,3-0,35
- air excess at the burner level: λ = 1,15-1,25
- air excess in the post combustion aria: λ_f =1,35-1,4
- air temperature: preheating in range of 100-250^{0}C
- primary air rate: $W_1 = 13 - 17$ m/s (according to Figure 5)
- secondary and tertiary air rate: $W_{as} = 25 - 40$ m/s
- turbulence degree for the secondary and tertiary air: n = 1,5-2,5

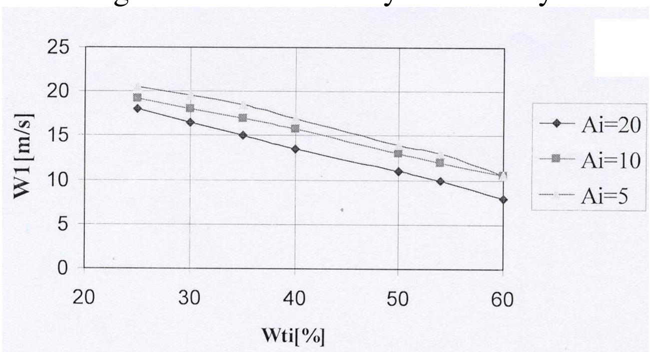


Fig. 5. The primary agent rate considering the balast from fuel (moisture and ash)

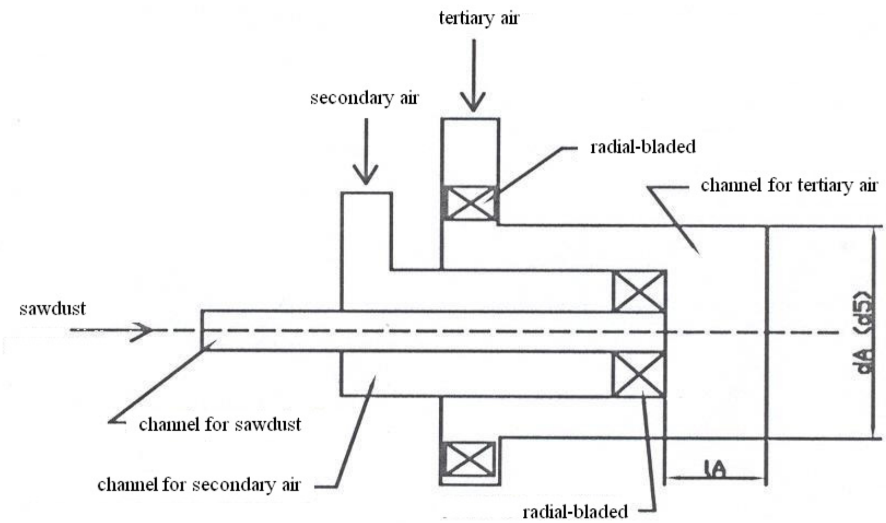


Fig. 6 The burner design

Figure 6 presents the design of a burner for sawdust combustion in suspension, to be installed at the 2MW pilot boiler from Polytechnic University of Bucharest. The burner will be mounted on the front of the boiler (Figure 7), replacing the pulverized coal burners.

Research will continue by construction of a installation for combustion in suspension technology in fluidized bed for a 55 kW boiler and the burner for the 2MW pilot boiler.

6. Conclusions

The experiments proved that biomass can successfully replace fossil fuels. It is possible to find solutions to surmount the main disadvantages of solid biomass supply in order to obtain a full automatic control of the processes and increase the comfort of the users.

Improvements of the equipments are conducted by the constructors and beneficiaries, with support of researchers from university.

Experimental tests revealed good figures for pollutant emissions (under regulatory limits) and efficiencies exceeding those of old stoves, approaching to solid fuels boilers.

R E F E R E N C E S

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