UTILIZATION OF THE CO-FIRING, WOOD/MINERAL COAL, IN FLUIDIZED BED COMBUSTION PROCESS TO PROMOTE ENVIRONMENTALLY SULFUROUSUS EMISSIONS IN SMALL THERMAL POWER PLANTS

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Abstract - The aim of this work is to present the results obtained in operations realized in pilot plant, which have demonstrated that the process in fluidized bed is appropriate to promote combustion environmentally correct of a mixed fuel composed by biomass and mineral coal in small thermal power plants -STPP.

Keywords: biomass, mineral coal, co-firing, clean energy

1. Introduction

The aim of this work is to demonstrate that the energetic utilization of mineral coal – MC – in Small Thermal Power Plants – STTP – can be realized with the environmental conditions connected to sulfur compounds emissions adequate to the one imposed by the brazilian standard – (NBR ISO 14001 – 1996) , since this utilization is done together with some supplementary fuel without sulfur concentration in its ultimate analysis.

In this work, due to the availability the supplementary fuel was wood chips (WC), which, with a suitable preparation, shows fluid dynamic characteristics that allow its utilization to the combustion process in fluidized bed together with mineral coal.

The activities for this project were divided in two parts: a theoretical one, with the purpose to characterizations of the mixed fuel and defining the theoretical parameters, and a practical one, that consisted of operations in a combustion pilot plant in order to obtain experimental data connected to combustion and gases emissions.

2. Characterization of wood chips and mineral coal

Specific characteristics were determined – ultimate analysis, heating value, air required, gases forms from the mixed fuel – MF- with the purpose to identify relations between WC and MC which establish the ideal mixing which guarantees sulfur emissions according to the standard that have already been quoted.

The characterizations of the coal used – Candiota CE – 3000 – and the wood chips are presented together with elementary analysis in wet basis as following. The humidity of MC was considered as 15 %, on average of five measures.

Table 1: Ultimate analysis of MC

Component	Mass %
Carbon	27.93
Hydrogen	1.78
Nitrogen	0.63
Sulfur	1.35
Oxygen	8.54
Ashes	44.77
Water	15.00

Source: CIENTEC

The wood chips – WC -, which comes from the Eucalipto tree, was prepared in a commercial crusher and presented a grain size 100% lower than 50 mm (grain size already highly tested in combustion with pilot plants in fluidized bed) in its biggest dimension and since 20 mm to lower dimensions.

The ultimate analysis to WC (considering an usual humidity of 30% in practice) is presented as following:

Table 2: Ultimate analysis of WC

Component	Mass %
Carbon	36.0
Hydrogen	4.50
Nitrogen	0.04
Sulfur	-
Oxygen	29.3
Ashes	0.16
Water	30.0

Source: CIENTEC

2.1 Characterization of the mixed fuel – MF –

The necessary parameters to study the mixed fuel – MF – were defined since the ultimate analysis, providing participations of the MC and PW, being the quantification of the mass of air necessary, heating value and composition of the gases formed the most important ones.

2.1.1 Reference elementary analysis of MF

The reference elementary analysis of the MF for this work was determined according to the maximum emission of sulfur dioxide – SO_2 – which could attend the conditions praised by (Resolução CONAMA,1990) for thermal plants until 70 MW_{el}, what means an emission until 1.2 mg / kJ.

In order to obtain the discharging the sulfur dioxide discharging of 1.2 mg / kJ the sulfur contained quantity at the fuel must be 0.6 mg / kJ. The SO_2 emission of the mineral coal used in this work is:

$$\text{MC - SO}_s \text{ emission} = 2.6 \text{ mg / kJ}$$

As can be realized, the SO_2 emission is over the limit imposed by CONAMA, so there is the necessity to apply some adequate proceedings to promote the desulphurization of the gases, or the addition desulfurants agents at the combustion zone, as limestone, or at the post combustion cleaning.

At the mixing with wood chips for several possible mixtures, in mass, the following control table was elaborated:

Table 3: SO_2 emission for several mixtures

MC (%)	WC (%)	SO_2 (mg/kJ)
100	-	2.6
60	40	1.8
50	50	1.2
40	60	.96
30	70	.71

In this work, the mixed fuel – MF – was considered as a mixture of 45% MC and 55% WC, and presenting SO_2 emissions of 1.1 mg/ kJ , being inside the values acceptable to thermal centrals until 70 MW_{el} power.

To the MF elementary analysis in wet basis (considering as a reference ultimate analysis) presents the following composition:

Table 4: Reference ultimate analysis for MF

Component	Mass %
Carbon	32.37
Hydrogen	3.30
Nitrogen	0.30
Sulfur	0.60
Oxygen	19.96
Ashes	20.22
Water	23.25

2.1.2 Heating value

The lower heating value for the MF in this project is referred to the mixture that have already been referred previously is:

$$LHV_{w.b} = 11156 \text{ kJ/kg}$$

2.1.3 Air required

The stoichiometric mass of dried air – M_{Aso}- calculated according to the stoichiometry of the elementary fuels (C,H,S) contained at the reference ultimate analysis has the following value:

$$M_{Aso} = 4.95 \text{ (kg/kg }_{MF})$$

Air excess: Due to materials characteristics of pilot plant construction it was used an air excess from 90% to 150%.

$$M_{Aut} = 9.41 \text{ to } 12.38 \text{ (kg/kg }_{MF})$$

3 Practical activities

The practical activities were done in a combustion pilot plant with a nominal capacity of 1.7 MW installed in CIENTEC'S Campus in Cachoeirinha – RS - and concerned at the determination of some parameters, as relative to the fluid dynamics, as to the combustion, which could serve as a basis for the use in steam generators. It had also been evaluated operational characteristics connected to the fluidization velocity and feed system.

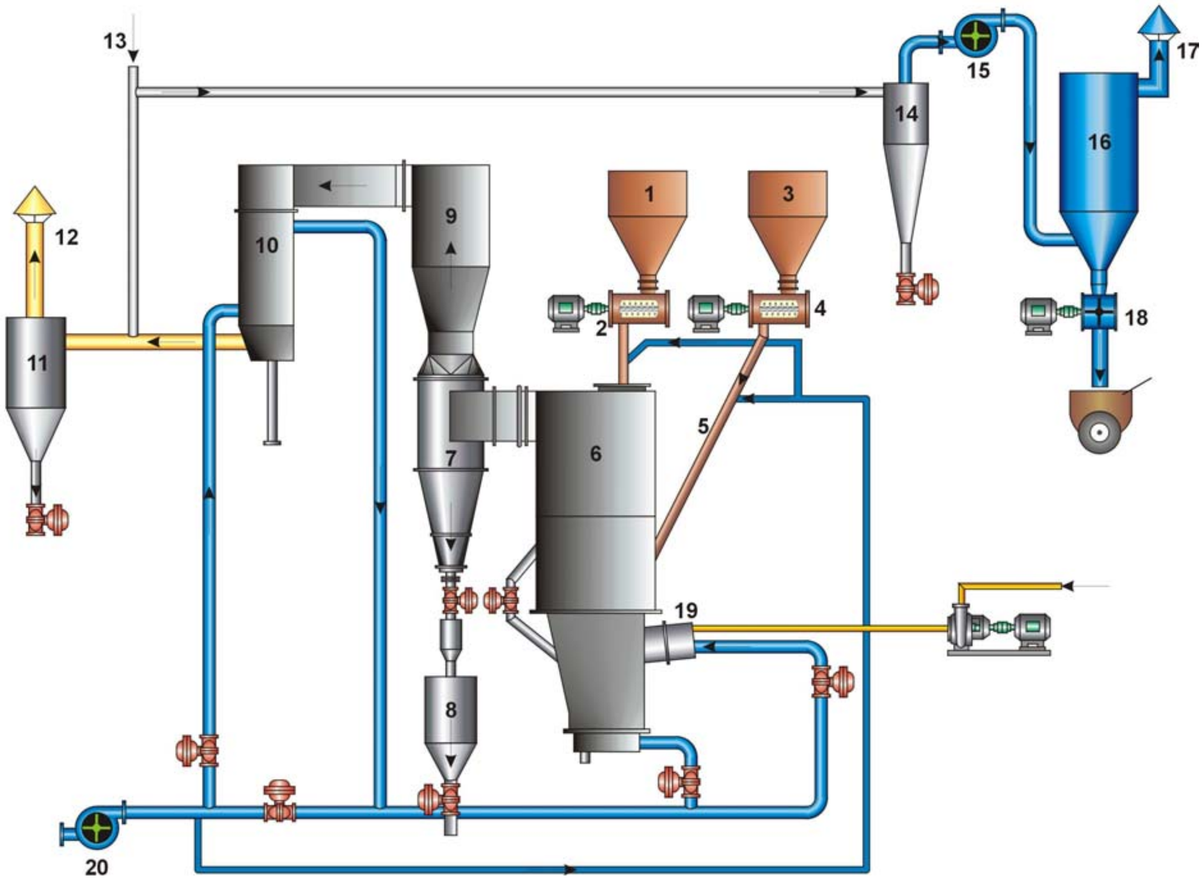

Figure A1 – Pilot Plant Flow Sheet

In the Figure A1 is showed the pilot plant flow sheet that was used for the work. The furnace (6) is composed of a retangular section body with 1.5 m^2 of bed area and 3.5 m of height. The start is perfomed with hot gases utilization that are generated from alcohol combustion in a auxiliary burner (19) till a temperature from 400^{o}C to 500^{o}C in the bed will be obtained then the fuel is injected, deriving from two storages bins (1) an (3), properly dosed individually by two screws feeders (2) and (4). The combustion and fluidization air is supplied through a ventilator (20) - capacity of 5500 Nm^3/h and 15.5 kPa of total pressure- and heating in a heat exchanger (10) before to go into the furnace. The ashes are abated by ciclones (7,11 and 14) or baghouse (16).

3.1 Minimum fluidization velocity in cold state

The minimum fluidization velocity had the objective to determine the air combustion and fluidization flow and should be used for the beginning of the operation in pilot plant. The minimum fluidization velocity in this project was determined for the mineral coal ashes due to its utilization as a support bed.

$$V_{mf\,CZ} = 1.2 \text{ m/s}$$

3.2 Feed system

Two feed systems were evaluated. The first one took in account the mixed fuel and deposited in a storage bin with only one feed, and the second was composed by two independent feed systems and MC and WC deposited and feed individually.

It was observed at the fuel feed system where is a previous mixing a degradation of the mixture internal to the storage bin, what implicates in an extremely heterogeneous feed and not adequate.

For this problem do not occur, individual systems of feed were used (one variable speed screw feeder for each storage bin). The MC is injected at 30 cm from the expanded bed and the WC directly over the bed across a heat-resistant stainless steel tube which does not allow volatile materials to get free before full into the bed.

3.3 Gas analysis

The gases from MF combustion were analyzed whit on on-line gas analyzer and showed one sulfur dioxide concentration less than 1.05 mg/kJ .

3.4 Loading rate

The operations conditions were valued from 800 kW/m^2 to 1500 kW/m^2 , the lowest value refers to minimum condition of combustion stability and the highest value refers to conditions of integral combustion internally to the furnace.

4 Conclusions

The following conclusions were drawn:

1. The moisture (55% WC and 45% MC in mass)utlized in the tests showed SO_s emissions below the maximun value allowable by CONAMA to thermal centrals until 70 MW_{el} power.
2. For apply in steam generator, taking into considerations a furnace equiped with water wall, the design data may be the followings: fluidization speed = 1,2 to 4 m/s: loading rate 900 to 1500 kW/m^2.
3. The best results were obtained from coal with grains size smaller than 2,5mm and wood with grains size smaller than 50mm.The results were obtained using Candiota Coal: cost of US$ 8.00 (eight American dollars) per ton.and biomass – wood chips- and cost of US$ 22.00 (twenty two American dollars) per ton.
4. The most economical mixtures (maximum coal consume), in mass, from which sulfur dioxide liberation by gases attend the brazilian standard emissions regulations was: 55% Candiota coal and 45% firewood,

5. The comparative costs from both steam generators with fluidized bed, supplied by HPB – Engenharia e Equipamentos, indicated the following: steam generator from coal: US\$ 700,000 (seven hundred thousand Americam dollars) by MW_{el} and from wood US\$ 500,000 (five hundred thousand American dollars) by MW_{el}.
6. On the whole, the mixed combustion of mineral coal and biomass in fluidized bed is perfectly appropriate to guarantee an environmentally suitable mineral coal utilization.
7. Once the introduction cost will be equivalent compared to biomass combustion systems and that the operational cost will be smaller than the one with mineral coal only, it is possible to conclude also that the proposition of this work guarantees one very competitive energy generation costs.
8. Although this work has been realized using wood chips, the mixed combustion process can be done with any fuel derived from biomass, as agroindustrial wastes, implying even in a reduction of operational costs.
9. The importance is that this process introduces an appropriated alternative for the energy generation in small thermall power plants at Rio Grande do Sul, which is the biggest producer and owner of the most mineral coal reservation in Brazil, besides the expressive production of biomass originating from wood and wastes.

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