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Combustion of Pakistani Lignite (Tharparkar coal) in a pilot scale pulverised fuel down fired combustion test facility

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Abstract

In this study, Pakistan's first and foremost pilot scale combustion test results of Tharparkar Lignite Block-8 have been reported. The reported data will be an addition to the existing literatureon lignite firing testing. In this paper NO, CO and CO_2 measurements were recorded at different axial locations in a down-fired combustion test facilityfor 2s, 2.3s and 2.6s of primary combustion zone residence times in a 4 meter long down-fired pulverised fuel furnace. The overall NO_x and SO_2 emissions have also been reported for un-staged and air-staged combustion conditions. The reported data (emissions and carbon burnouts) is for fuel to air stoichiometric ratios of 0.9, 1.01 and 1.16 near the burner zone. The fly ash sample were analysed and the percentage of iron oxide was found in the range of 18-21% whereas the percentage of alumina concentration was in the range of 14-16% for varying stoichiometric ratios. Furthermore, slagging and fouling analysis has also been carried out on the collected ash samples during testing.

Key Words:

Pakistani Lignite Coal; Emissions; Residence time; Stoichiometric ratios;Carbon burnout; Slagging and fouling indices

1. Introduction

Both developed and developing countries have been exploiting vital lignite coal resources for power generation. In recent years, countries such as Germany, Poland, Turkey, Serbia, Czech

Republic and Greece have increased their lignite production to about 440 million tonnes[1].Global lignite coal productionhas reached 1.0 billion tonnes and still has massive potential for growth[2]. Pakistan's lignite coal reserve of 176 billion tonnes has an electrical potential equivalent of 100,000MW[3]. This would enable the mitigation of the present electricity shortfall and also enable the country to meet any electricity demand in the future. In order to attract investment in coal fired power plant the GOP drafted a new set of incentives which, offer attractionto investors as well as keep consumer prices within affordable limits. Keeping in viewthese objectives, the Policy for Power Generation 2002 was formulated so as to offer maximumincentives and assurance to investors. In the Power Policy 2002, the main emphasis was on the development of power projects based on indigenous fuel resources, especially coal andrenewables[4].

Co-firing of firewood and lignite has been proven to exhibit acceptable temperatures, combustion efficiency and low emissions at low (50kW) to high (150kW) thermal outputs[5].Similarly, lignite combustion resulted in stable operation with remarkably low NO emission levels with stoichiometric conditions around 0.9[6]. The concept of ignite co-firingat a 10% biomass Cynara cardunculus (cardoon) thermal share for a 330 MWe pulverized fuel plant in Northern Greece is investigated.In most co-firing cases, CFDresults indicated that the substitution of lignite with biomass has minimal impact on the plant operationalparameters as well as has the potential for NOx reductions[7]. It is also worth mentioning that before practical use, lignite coal has to be dried to reduce inherent moisture. Out of available technologies WTA (waste heat utilization) technology developed by RWE Power can technically and economically is suitable for lignite-based electricity generation[8.]

In Pakistan there are discussions and plans for co-firing of indigenous coal specially Thar lignite with imported or locally sourced biomass. Keeping in view the future need of power plants in Pakistan a series of tests have been performed on a 50kW$_{th}$ combustion test facility (CTF)in order to understand the combustion characterization of PakistaniThar lignite.

The present study expands the main combustion product concentrations (CO,O_2,NO$_x$, SO$_2$, LOI) data bank for lignite coals; especially in terms of scarcely reported pilot scale combustion trials

on Pakistan's Tharparkarlignite coal. This reported data would support the research and development phase for establishing new lignite based power plants to overcome the energy crises in Pakistan.

2. Experimental Setup

The schematic combustion test facility (CTF) comprising a down-fired pulverised coal fired furnace 4min length with an internal diameter of 400mm is shown in Figure 1. The burner was operated at an input feed rate of approximately 10.5 kg/hr of Pakistani lignite resulting in a net thermal input of about 50 kW$_{th}$. The actual combustion test facility is designed to be operated at 100kWth but due to the limited availability of the coal (especially sourced via bore drilling after travelling nearly 960 miles) resulted experiments to be performed at lesser heat input rate of 50kWth. Hence lesser coal sufficient to give 50kWth input was fed in a 100kWth combustion test facility. The major flue gas species CO_2, O_2, NO_x, and CO were measured at the furnace exit. Gas samples were constantly drawn through water cooled stainless-steel probe to the gas sampling system so that the correct combustion conditions could be set in the furnace. The extracted flue gas from the probe was transferred via Poly Tetra Fluoro Ethylene (PTFE) tubing through a series of filters and water traps for cleaning and drying purposes. The flue gas was then cooled to 2^0C (which is a requirement for safe operation of the gas analysers) by passing it through a chiller. The filters were frequently replaced and the water traps were regularly cleaned to prevent any blockage in the gas sampling system. The flue gas was passed through a manifold that directed the sample gas to different gas analysers. To prevent any blockages during operation, the gas sampling probe was regularly purged using a compressed nitrogen supplywhich was connected to the sampling probe (utilized for drawing in flue gas from the furnace). O_2, CO_2, CO, NO (NO_x) and SO_2emissions were monitored in real-time by gas analysersand temperatures down the furnace were monitored and all data was logged on a PC in real-time as all the tests were carried out.

Flyash solids were collected in a fly ash catchpot connected to a cyclone separator. The samples and emissions were collected and measured, respectively, after attaining steady state conditions for each test. Fly ash samples were analysed for loss on ignition (LOI) in a muffle

1 furnace by firstly, drying them at a temperature of 105^0C for one hour and secondly, further

2 heating the samples to 850^0C and then holding that temperature for 2 hours.
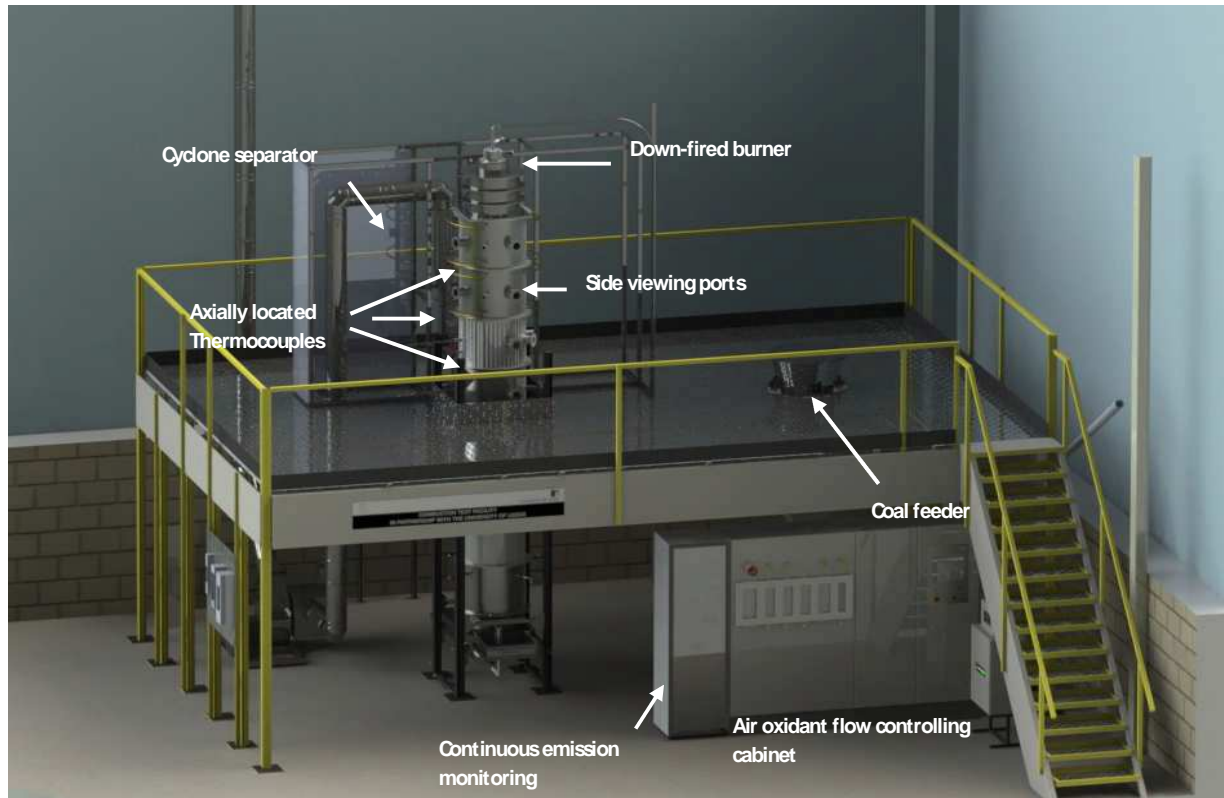
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4 **Figure1.** 50 kW$_{th}$ combustion test facility (CTF).

5 **3. Results and Discussion**

6 The ultimate and proximate analysis, evaluation of gross calorific value and particle size

7 distribution of Thar coal are shown in **Table 1**. To compare the properties of the Thar lignite,

8 two other brown coals are also reported in this table. In **Table 2**, we can observe the positions

9 of the thermocouples and their axial distances from the burner. An ultimate and proximate

10 analysis was performed using a CE Instruments Flash EA1112 Series Analyzer and Shimadzu

11 TGA-50 Thermogravimetric Analyzer, respectively. The calorific values were determined by

12 using a Parr 6200 Oxygen Bomb Calorimeter. The particle size distribution of the sample was

13 analysis using laser diffraction in a Malvern MasterSizer-2000. In **Table1** the average particle

14 sizes are expressed as the volume mean diameter, D[4,3]; whereas d[0.1], d[0.5] and d[0.9] are

15 the diameters determined at the 10th, 50th and 90th percentile of the undersized particles. The

1   particle size analysis shows that the 90% of the coal sample is less than 250 µm, which fulfil the

2   design requirement of the CTF.

3   **Table 1.** An ultimate, proximate analysis and particle size distribution of Tharparkar lignite coal along

4   with some reference values of brown coal.

Fuel	Ultimate Analysis[a]					Proximate Analysis[a]				GCV[a] (MJ/kg)	Moisture[a] (%)
	C (%)	H (%)	O[b] (%)	N (%)	S (%)	Ash (%)	FC (%)	VM (%)	VM/FC (-)		
	36.39	4.21	7.76	0.64	2	14	20	31	1.55	9.53	35
Thar Lignite	Particle size analysis [a]										
	D[4,3] (µm)		d [0.1] (µm)			d [0.5] (µm)			d [0.9] (µm)		
	99.69		5.69			57.02			257.15		
Greek lignite[7]	61.95	4.3	31.2	1.65	0.84	27.61	17.17	19.01	1.1	8.06[c]	
Rhenish Lignite[9]	67.6	4.96	26.3	0.66	0.42	3.91	12.56	20.0	1.59	8.171[c]	58.4

5   [a]as received basis except as denoted in table; [b]calculated by difference; FC= fixed carbon;

6   VM= volatile matter; GCV= gross calorificvalue; D[4,3]=volume mean diameter; d[0.1],

7   d[0.5] and d[0.9] are the percentile diameters determined at the 10th, 50th and 90th

8   percentile of the undersized particles, [c]Net Calorific value (the values for ultimate analysis

9   are dry ash free basis.

10   **Table 2.** Vertical positions of thermocouples and sampling ports.

Thermocouple location	Axial position from the burner (mm)	Port location	Axial position from the burner (mm)	Experimental studied stoichiometric ratios (λ) or staging levels
T_1	804	Port 1	1685	Un-staged 16% overall excess air
T_2	1307	Port 2 (staged air)	1810	11% level of staging near combustion zone, λ = 1.01
T_3	1810	Port 3	2691	22% level of staging near combustion zone, λ = 0.9

T$_4$	2313	Port 4 (flue)	4050
T$_5$ (flue)	4050		

3.1 NO$_x$, CO, O$_2$ and SO$_2$ measurements

The changes of experimental conditions during trial always influence in-furnace conditions, therefore, in order to remove any dilution of the pollutants in the process, the values of NO and SO$_2$ are standardised at 6% O$_2$ in the flue gas using the following equations.

$$NO \, @ \, 6\%O_2 = NO \, \frac{[20.9\% - 6\%]}{[20.9\% - O_2\%]} \qquad (1)$$

$$SO_2 \, @ \, 6\%O_2 = SO_2 \, \frac{[20.9\% - 6\%]}{[20.9\% - O_2\%]} \qquad (2)$$

where NO and SO$_2$ are the measured concentrations in flue gas (ppmv) and O$_2$ is the measured concentration in flue gas corresponding to the set condition. NO and SO$_2$ reduction (%) was evaluated by using Eq.(3) and (4) in which coal baseline was used as a reference for comparison.

$$NO \quad red \, \% = \frac{\left(NO_{coal \; baseline} - NO_{biomass - coal \; blends} \right)}{\left(NO_{coal \; baseline} \right)} \qquad (3)$$

$$SO_2 \quad red \, \% = \frac{\left(SO_{2 \; coal \; baseline} - SO_{2 \; biomass - coal \; blends} \right)}{\left(SO_{2 \; coal \; baseline} \right)} \qquad (4)$$

Both bituminous and sub-bituminous coals produce volatile-N during volatilization mainly in the form of tarry compounds which further decay into HCN and soot-nitrogen. In contrast low rank coals such as lignite due to lower fixed carbon and higher volatile matter directly liberate the

6

1 lighter nitrogen species such as NH_3[10, 11].In a recent publication on 3-D CFD modelling of a 1.2

2 MW_{th} CFB it is reported that for lignite the HCN released is negligible particularly during char

3 combustion[12]. In order to examine the difference in the combustion performance of Thar coal,

4 the average concentration of O_2, CO and $NO_x$was recorded along the vertical axis of the CTF for

5 stoichiometric ratios of 0.9, 1.01 and 1.16.

6 A highest concentration of about 19% for CO was observed at an axial distance of 1685 mm

7 from the burner at a stoichiometric ratio of 0.9, whereas CO concentrations of 8% and 2.5%

8 were observed for 1.01 and 1.16 stoichiometric ratios, respectively**(Figure 2A)**. These CO

9 concentrations signifythe existence of a fuel-rich zone close to the burner at lower O_2(oxidant)

10 concentration. This is in agreement with a recent study where it is reported that during

11 devolatilization,hydrocarbon species (C_xH_y), hydrogen (H_2), water vapor (H_2O),

12 carbonmonoxide, carbon dioxide (CO, CO_2) and tars are released[12]. In another study it is

13 observed that generally, peak CO concentrations are high in the regionswhere temperature

14 peaks are also predicted[13]. These values also indicate poor combustion conditions near the

15 burnerat lower stoichiometric ratios. However, the decreased concentration in the measured

16 CO and increased oxygen concentration (measured)demonstrate better fuel-lean combustion

17 conditions at stoichiometric ratio of 1.16.It can be observed in **Figure 2A**that the CO axial

18 profilesexhibit a sharp drop after the injection of overfire air. This indicated stable and

19 complete combustion. Similarly, the oxygen concentrations were observed to increase from

20 lessthan 1%to about 3.4%for changing stoichiometric ratios in fuel-rich zone.

21 An increase in the stoichiometric ratio near the burner convertsthe fuel-rich conditions to fuel-

22 lean and this partly delays the mixing of Pakistani lignite with air resulting in a reduction in NO

23 emissions**(Figure 2B)**. The calculated value of residence times for the fuel-rich zone increased

24 by 23% from 1.16 to 0.9 stoichiometric ratios. This is indicative of the delayed mixing of fuel

25 with oxidant, resulting in controlled in-furnace reduction of NO emissions via air-staging. The

26 lignite coal combustion is deemed to produce higher concentrations of NH_3 in the flame-rich

27 zone due to its poor grade, thus resulting in N_2 production pathway instead of NO[14]. This leads

28 to an in combustion reduction via selective non catalytic reduction phenomena for reduction of

1   NO to N_2[15]. It can however be seen that discrepancy on part of the oxygen measurement is only

2   for staging experiment believed to be due to poor mixing especially in the post over fire

3   injection zone i.e. fuel lean zone. This poor mixing between the remaining combustibles in the

4   fuel lean zone i.e. post over fire injection zone resulted in laminar regions at the exit of the

5   furnace resulting in variation of about 1% in oxygen. This also suggests the combustion would

6   still be taking place even close to the furnace exit because of poor mixing. This is also indicative

7   in the variation of carbon in ash results.   This can be confirmed by the variation in carbon

8   burnouts. It was also witnessed that the flame during the staged experiments was extending

9   deep into fuel lean zone (i.e. about 1000mm further down from 1810mm (over fire air injection

10 port). However the reasons for stable CO emissions are unexplainable.

11 Pakistani lignite despite being high in ash and low in fixed carbon content exhibited complete

12 combustion.It is evident from experimentation that the Pakistani lignite coal produced overall

13 NO emission levels below 190 ppmv @ 6% O_2 for 16% excess air levels. This corresponds to

14 being substantially lower than other bituminous and low ranks fuels reported in literature[6, 16,

15 17]. **Figure 3** demonstrates the overall NO and SO_2 emissions and corresponding reductions

16 corrected at 6% O_2 levels for 0.9, 1.01 and 1.16 stoichiometric ratios.The reported residence

17 times are calculated for gases, it is also found that residence time increases with decrease in

18 the stoichiometric ratio. To avoid any confusion and to simplify the measurements thus making

19 them more understandable, the results are reported on concentration basis (i.e. ppmv or

20 mg/Nm^3 @ 6%O_2) rather than energy specific basis (i.e. mg/kW_{th}). It is worth noting that due to

21 the presence of high amount of inherent sulphur, the SO_2 emissions were in the range of

22 1380ppmv to 1550ppmv (@ 6%O_2) for 0.9 to 1.16 stoichiometric ratios, whereas the overall NO

23 emissions were in the range of 65 ppmv to 165 ppmv (@ 6% O_2), respectively. An overall

24 reduction of about 10% in SO_2 and 60% in NO_x can be achieved with a simple in-furnace air-

25 staging combustion technique, i.e. 22% level of air-staging.There is a possibility that in air-

26 staged combustion system the inherent sulphur of the Pakistani lignite reacted with CaO

27 present in the ash to form CaS especially in the fuel-rich zone later being converted to $CaSO_4$ in

28 the burnout zone[18]. This has resulted in a reduction in SO_2 emissions during air-staged

29 combustion.
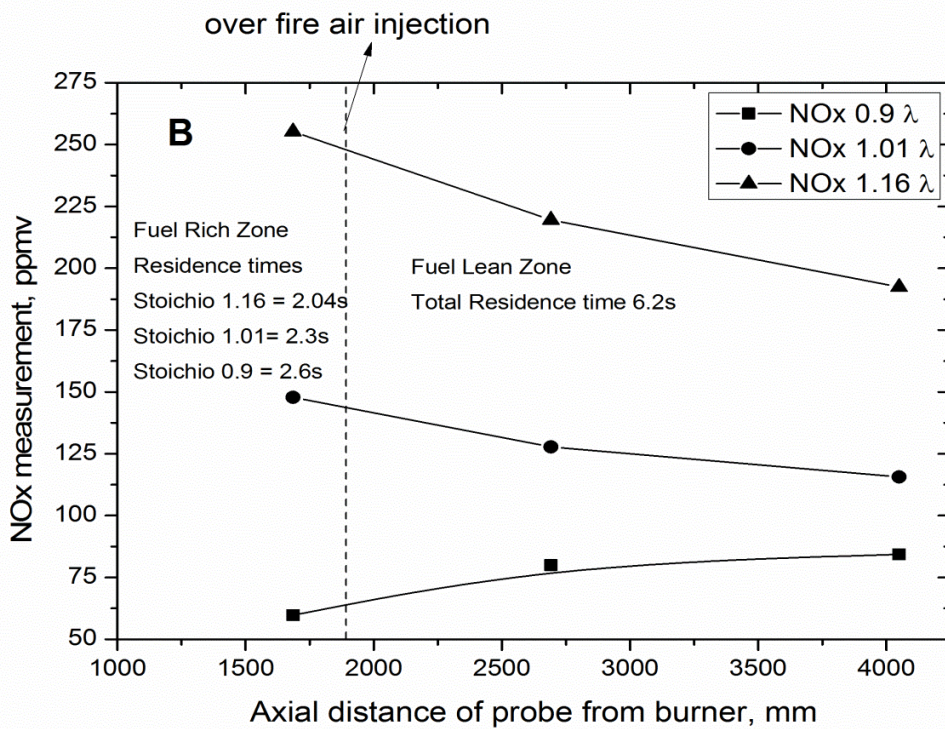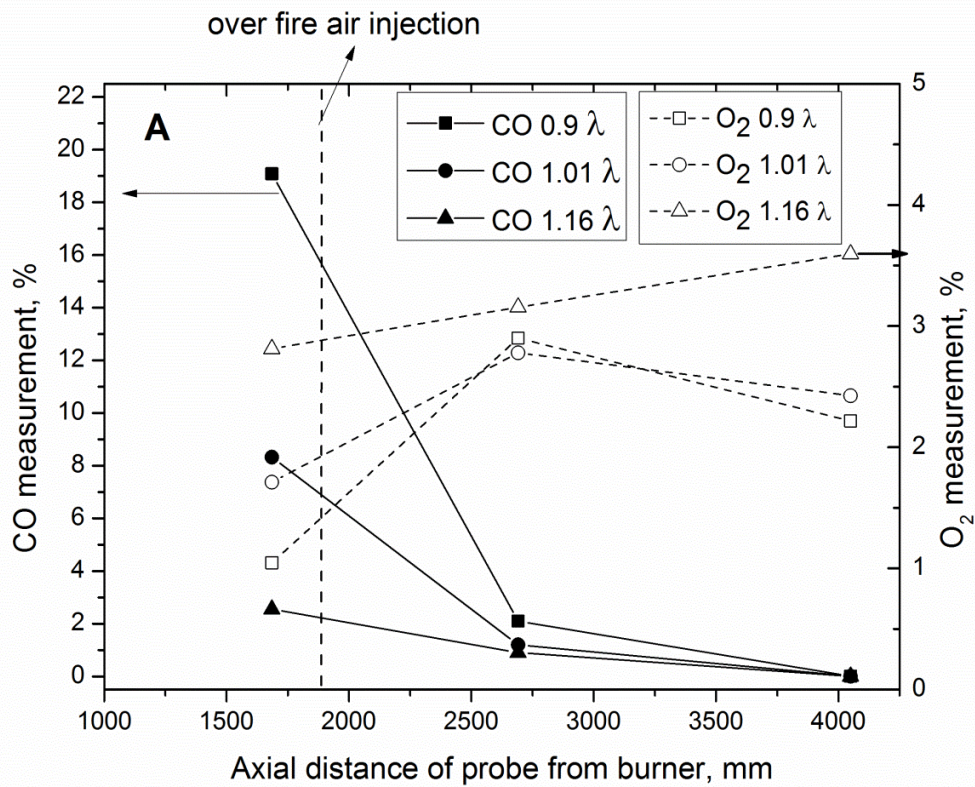
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2   **Figure2.**Axial concentration (CO,O_2, NO$_x$) profiles for 0.9, 1.01 and 1.16 stoichiometric ratios (λ).
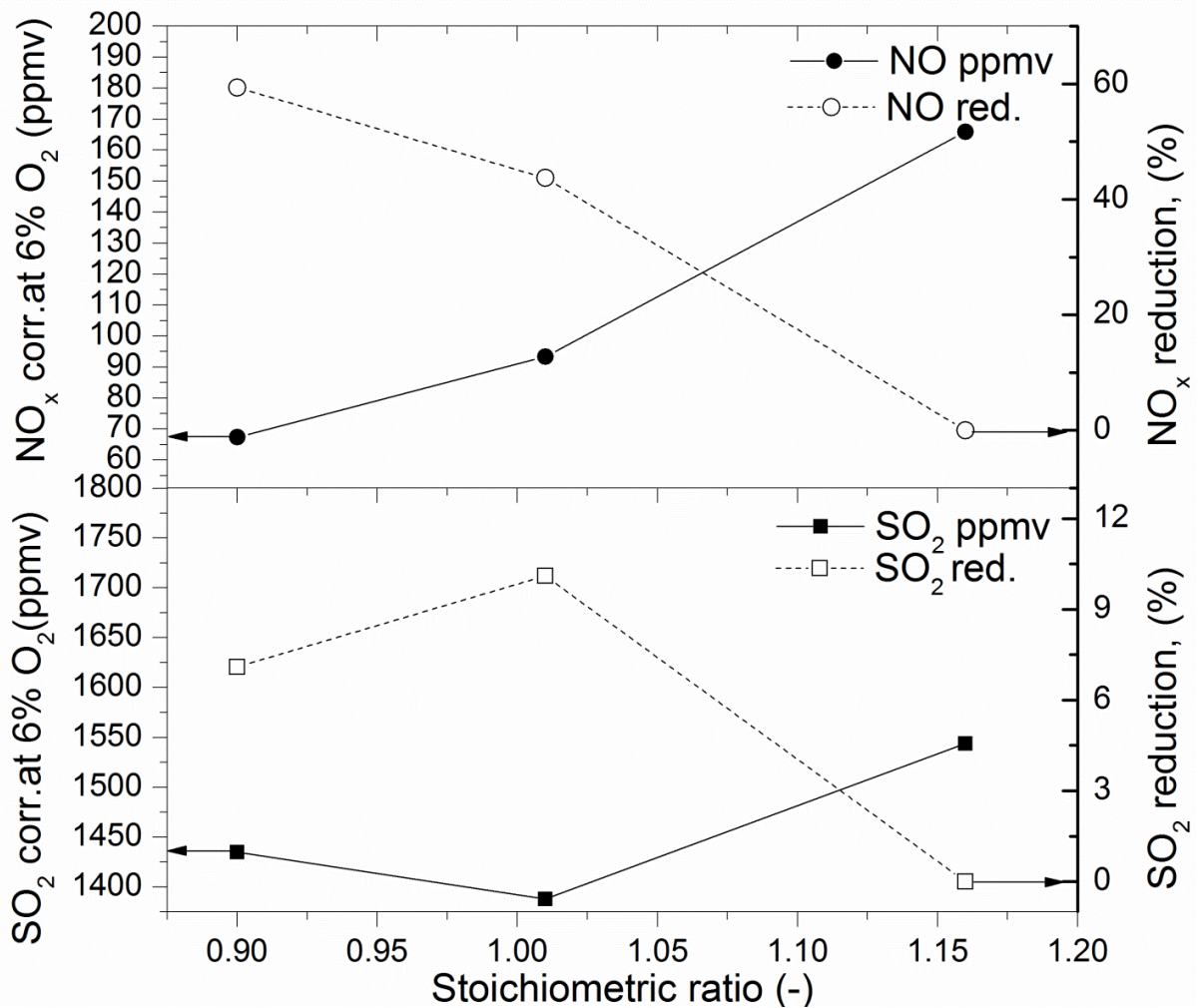
Figure3. NO_x and SO_2 emissions for 0.9, 1.01 and 1.16 stoichiometric ratios.

3.2 Effect on temperature and carbon burnout

The process of coal combustion (i.e. combustible matter such as volatiles/hydrocarbon species)releases major amounts of heat in close proximity to the primary combustion zone. Hence, the temperature in the primary combustion zone is higher than the rest of the furnace at fixed values of stoichiometric ratios. However, since air-staged combustion delays the fuel so that excess oxidant mixing occurs, this results in marginaldifferences between the air-staged and unstaged primary combustion zone temperatures. The temperatures of the primary combustion zone under air-staged combustion are less than the unstaged fuel baseline. Similarly, it has also been reported that under air-staged coal combustion marginal temperature differencesnear the exit of the furnaceare produced when compared to un-staged

1 coal combustion. This is partly due to the combustion of residual combustibles entering from

2 the fuel-rich to fuel-lean zone[18-19]. In this study, a noticeable 40-50^{0}C temperature differenceis

3 observed amongst tested stoichiometric ratios in the main primary combustion zone. However,

4 this difference is almost minimized to about 5^{0}C near the furnace exit. This indicates that the

5 existing 16% overall excess air level (both for staged and unstaged air levels) is enough for a

6 high degree of complete combustion of Pakistani lignite. It is also known that with the control

7 of local peak flame temperatures and increasing residence times of the primary combustion

8 zones, the NO formation (mainly thermal NO_x and fuel-NO_x) can be controlled **(Figure3-4)**[19].
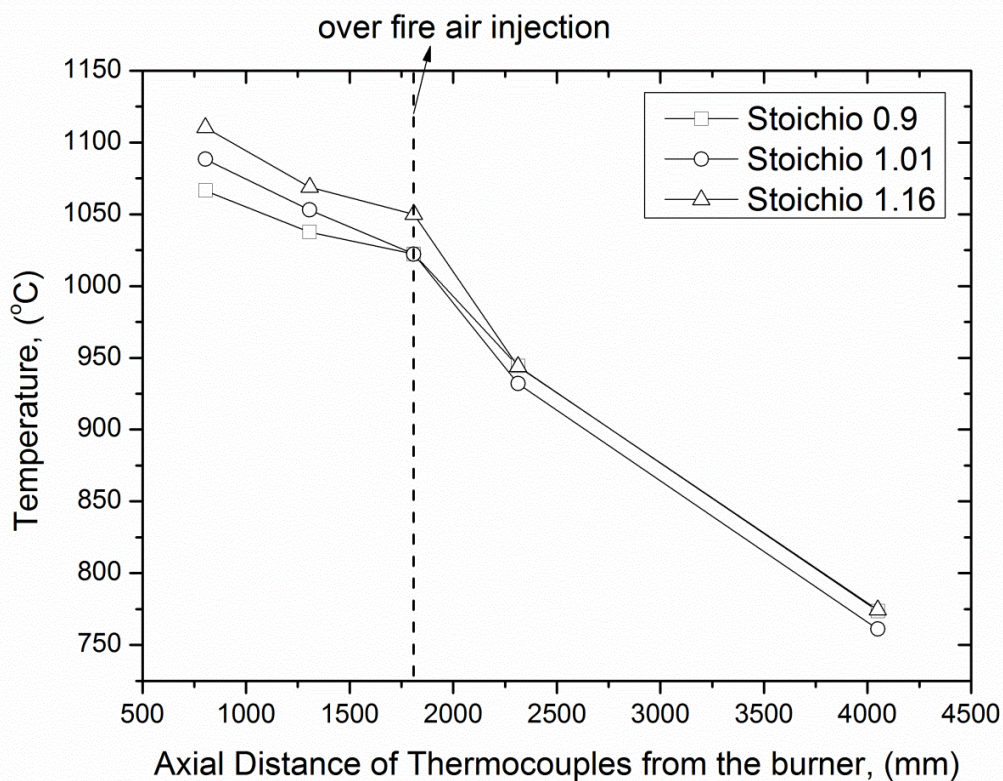
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10 **Figure 4.** Temperature measurement for 0.9, 1.01 and 1.16 stoichiometric ratios.

11 The ash samples for the lignite coal collected under different air-staged combustion conditions

12 were analyzed to determine carbon burnout using the following ash tracer method:

$$\text{Carbon burnout} = \frac{\left[1 - \left(\dfrac{z_k}{z_x}\right)\right]}{\left(1 - z_k\right)} \qquad (5)$$

Where:z: dry ash mass fraction, k: ash content in the input solid fuel and x: ash content in the char sample.

Figure5demonstrates the impacts of the variation of residence time of the primary combustion zone on carbon burnout. Lengthened residence time in the primary combustion zonecausesmarginally poor overall combustion efficiency due to the shorter burnout zone which is further compounded by lower temperatures within the primary combustion zone[20]. However, in the existing pilot-scale combustion tests the primary combustion zone temperature difference between20 un-staged and 22% level of air-staged combustion is 40^0C-50^0C; thisis effectively reduced to 5^0C up to the flue section of the furnace.At 16% excess air un-staged firing condition an overall carbon burnout level of 99.92%was obtained as compared to 90.56% carbon burnout obtained at 22% level of air-staging. This suggests that an overall NO_xreduction of 60% witha corresponding carbon burnout of 92.56%at 22% level of air-staged combustion condition is a feasible condition for Pakistani lignite combustion at a larger scale. Hence, 92.56% of carbon burnout result for 0.9 stoichiometric ratios or 22% level of air-staging arenot the only advantagesin terms of reduced NO emissionsbut are also accompanied by a lesser impact on the overall combustion performance.
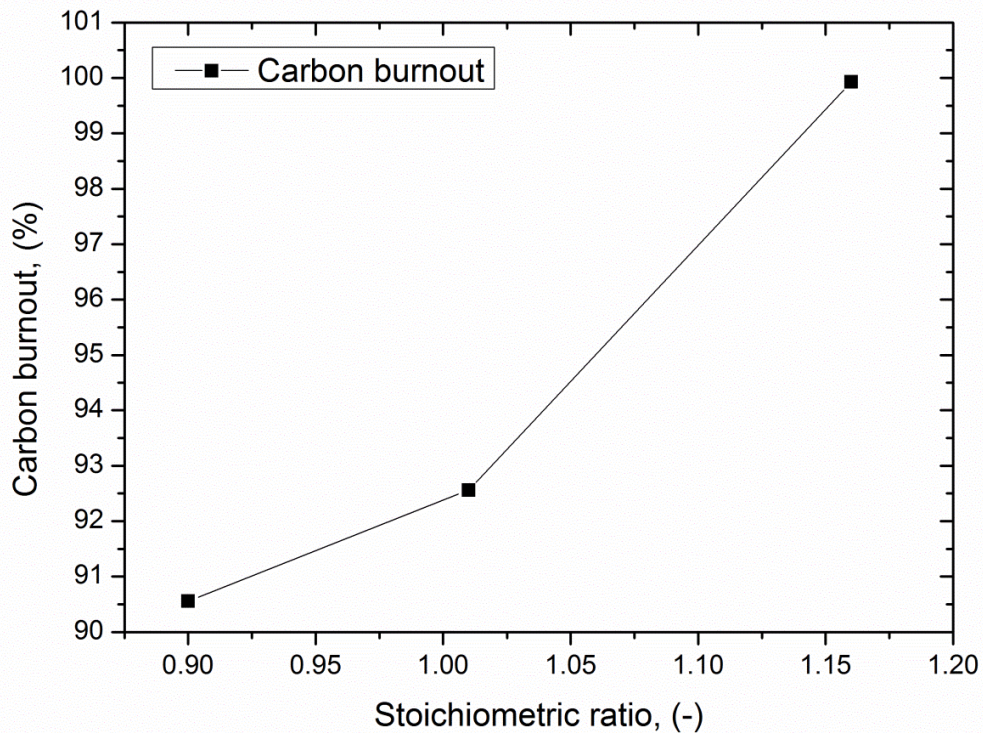
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2 **Fig. 5.** Carbon burnout for Pakistani lignite.

3 3.3 Effect on slagging and fouling propensities

4 Pakistani lignite coal ash samples collected from the pilot-scale combustion tests have been

5 analysed using XRF technique**(Table 3)**. The reported oxides of main heavy metals are utilized

6 to establish slagging and fouling characteristics of the deposits which collect on the radiant and

7 heat recovery section of boilers, respectively.In previous work[21-22], the slagging and fouling

8 indices have been used to assess the propensity of fuel ash which generally causesheat transfer

9 and corrosion related issues.

10 It is observed in **Table 3** that the reported chemical composition of the fly ash samples

11 indicatesvery high levels of Na_2O, K_2O and CaO resulting in higher values of basic to acidic ratios

12 of oxides. This has a direct influence on the slagging and fouling tendency of the resultant ash

13 formations. The overall values for both fouling and slagging propensities were in the high to

extremely high range indicating the necessity of boilers capable of compensating for higherlevels of corrosion and lower heat transfer in the super heater and heat recovery sections of the boiler. During some combustion trials on a pilot FBC it is reported that Polish coal presents highertendency for slagging and fouling than the Colombian coal[23]. It is suggested that a detailed analysis on the slagging and fouling tendency should be performed to understand the interactions of co-firing Thar lignite and other fuels for power generation. Slagging and fouling deposits from a pulverized lignite fired power plant at West Macedonia, Greece was investigated.The major chemical constituents found were Fe_2O_3,CaO and SO_3, while considerable contents of SiO_2 and Al_2O_3were also detected[24]. In another study twenty samples from a main seam of Panian coalfield in Semirara Island, Antique Province, Philippines, were collected. Chemical analysis of the ash revealed high contents of Na, Mg, Fe, Ca, Ba and Sr. The strongly negative correlation of these elements with theash content indicates an organic affinity of the chemical elements of the seam. Owing to enrichment in alkali and alkali-earth elements,slagging and fouling indices indicate that the seam has medium to high propensity for slagging and a severe tendency for fouling[25].

In this study the percentage of iron oxide was found in the range of 18-21% whereas the percentage of alumina concentration was in the range of 14-16% for varying stoichiometric ratios. The concentrations of Na_2O and K_2O are generally dominating factors towards the fouling propensity in commercial boilers. The percentage of K_2O is in the range of 0.5-0.8% whereas Na_2O is found in the range of 13-15%. The study also reported that the composition of these metallic oxides present in Tharparkar Lignite coal fly ash falls within the range of general lignite coal fly ash samples except iron oxide. Moreover, the combined percentage of oxides of Al, Fe and Si is about 67% close to 70% recommended for Portland cement blending.These percentages would have a direct non- trivial impact on the actual boiler furnace wall.It is important to mention that aside from the concentration of iron, sodium and potassium elements in oxide form, it is also important to know that what phases these oxides are present in product fly ash. The presence of iron oxide in resultant coal fly ash is mostly either in fayalite or magnetite phases. If present in magnetite form would be beneficial towards fire side tube passivation. Hence presence of iron oxide in magnetite form would help to mitigate the fire side

1   corrosion. Similarly the presence of aluminosilicate phases helps towards mitigating the basic to

2   acidic ratio which then compensates the higher slagging and fouling propensities.

3   **Table 3.**Metal oxides present in Pakistani lignite coal ash samples at 1.16, 1.01 and 0.9stoichiometric
4   ratios.

Metal Oxides	Unstaged Pakistani lignite coal ash (SR= 1.16)	11% air-staged Pakistani lignite coal ash (SR= 1.01)	22% air-staged Pakistani lignite coal ash (SR= 0.9)	Typical [26]Lignite coal metal oxide present in fly ash
SiO_2	31.82	35.22	31.22	15-45
TiO_2	2.43	2.06	2.43	-
Al_2O_3	16.21	14.43	16.19	10-25
Fe_2O_3	17.95	21.27	18.34	4-15
MnO	0.12	0.93	0.12	-
MgO	0.60	0.30	0.50	3-10
CaO	15.49	12.10	16.48	15-40
Na_2O	15.40	13.00	14.30	0-6
K_2O	0.56	0.87	0.53	0-4
P_2O_5	0.1090	0.1020	0.11	-
SO_3	0.10	0.08	0.09	0-10
ZnO	0.0006	0.0016	0.0006	-
CuO	0.0010	0.0020	0.0009	-
PbO	0.0001	0.0003	0.0001	-
$\left(\dfrac{B}{A}\right)=\left(\dfrac{Fe_2O_3+CaO+MgO+Na_2O+K_2O}{SiO_2+Al_2O_3+TiO_2}\right)$[14-15, 21]	0.99	0.92	1.01	
$Simplified\left(\dfrac{B}{A}\right)=R_{\left(\frac{B}{A}\right)}=\left(\dfrac{Fe_2O_3+CaO+MgO}{SiO_2+Al_2O_3}\right)$[14-15, 21]	0.71	0.74	0.68	
$R_b=Fe_2O_3+CaO+MgO+Na_2O+K_2O$[14-15]	50.00	50.15	47.54	
$Fu=\left(\dfrac{B}{A}\right)(Na_2O+K_2O)$[14-15]	15.81	14.92	12.75	
$Rs=\left(\dfrac{B}{A}\right)S^d$[14-15]where S_d = % of S in dry fuel	3.04	3.09	2.82	
Fu≤0.6 low fouling inclination; Fu = 0.6-40 high; Fu≥ 40 extremely high				
Rs< 0.6 low slaggingInclination; Rs = 0.6-2.0 medium; Rs = 2.0-2.6 high; Rs> 2.6 extremely high				
B/A = Basic to acidic ratio; Rs: Slagging Index; Fu: Fouling Index				

5

6

4. Conclusions

Lignite coal obtained from Pakistan's largest coal reserve in Tharparkar, Sindh(Block-VIII)was combusted in a 50kW$_{th}$ pilot-scale combustion furnace test facility. It was found that under a normal fuel to air ratio of 1.16 maximum NO$_x$ emissions of 165 ppmv at 6% O$_2$ levels were observed. However, at 22% level of air-staging a maximum NO$_x$ reduction of 60% was achieved to lower the NO$_x$ emissions to 65ppmv at 6% O$_2$. A noticeably higher level of inherent sulphur resulted in SO$_2$ emissions in the range of 1380ppmv to 1550ppmv (@ 6% O$_2$) for 0.9 to 1.16 stoichiometric ratios. An overall carbon burnout of 99.92% was obtained for 1.16 stoichiometric ratio near the burner as compared to a carbon burnout of 99.56% for 0.9 stoichiometric ratioin the burner zone. The overall values for both fouling and slagging propensities were in the range of high to extremely high further indicating a dire need of either injection of specialized chemicals in the boilers to compensate for higher levels of corrosion and lower heat transfer in the boiler super heater and heat recovery sections or blending of lignite coal with relatively better quality coal.

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