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CHARACTERIZATIONS OF SOME NIGERIAN BED MATERIALS FOR FLUIDIZED BED COMBUSTOR

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Abstract:

Bed materials processing involves solid minerals reduction to sizes of about 100-600μm and density of about 1400-3000 kg/m^1. Apart from the physical criteria, the chemical properties were also essential in respect of its absorbent and agglomeration effects in the fluidized bed combustor. In this work, we present the process technology to produce and select bed materials from Nigerian solid minerals. Firstly, the chemical composition of the various processed bed materials were determined using wet chemical method. Secondly, we subjected the materials at 100μm to dustiness test which provided the proportion trapped by the cyclone and filter. Nigerian bed materials were high in qualities and they met the requirements of fluidized bed combustion technology.

Introduction:

Fluidization is a technique which transforms solid particles into a fluid like state and suspended by the upward flow air. A bed is a suitable container in which solid and gas contacts can take place and heat exchanger tubes immersed to extract heat energy of the fuels. The process takes place in a combustor which is a rig, plant or furnace that may range from refractory brick to steel vessel. The sizes and shape vary so also the internal arrangements. Fluidized bed combustion therefore, implies burning of ground solid fuels of particles (6-20mm) placed on top of a perforated plate called air distributor. Air was blown from beneath the grate with such a speed that the fuel particles are lifted and suspended while burning in the furnace. Fluidized bed technique of burning coal has sufficient efficiency and environmental friendly records over conventional coal burning systems (Kunni and Levenspiel, 1991). The technology is over due for Nigeria in utilisation of coal, biomass and municipal waste-fired combustion for electricity generation. The properties of bed materials which are solid materials act as solid reactant and insulator to the air distributor (Rao and Parulekar, 2004). It also holds the heat as well as fuel for the combustion and heat exchanger. The granulated solid material when heated induces chemical absorbent and its continuous gas and solid contact induces heat transfer on the heating surface of the combustor (Kunni and levenspiel, 1991).

Bed materials include silica sand, zirconia, alumina, gypsum, kaolin, limestone, dolomite, mullite and calcites (Boore, 2008). The characterizations

were properties of the materials, the size grading and its effect on heat exchanger and dust collecting system (Crawford, 1980). Silica sand is an inert bed material but is very erosive and it can cause wear of heat surfaces. Calcined limestone is not entirely satisfactory because limestone catalyze nitrogen dioxide formation from nitrogen containing fuel sources thereby, causing an additional pollutant. Kaolin is particularly effective when molar ratio of Al/Na and K is at least 1.0 (Anon, 2008)

Size distribution of materials had profound influence in resistance to fluid flow, drag force and fluidization of the bed materials. Hence materials were classified based on particle density and sizes according to Geldart's groups: 'A','B','C' and 'D' i.e.≤1400kg/m^3 and 20-100µm; 1400-4000kg/m^3 and 40-500µm; 100-1000kg/m^3 and 30µm; and 2000-4000kg/m^3 and ≥ 600µm respectively (Botterill, 1983 and Gupta, 2005). When materials were fluidized, it means the gas velocity was able to overcome the pressure drop across the bed which is equal to its weight per unit area (Kunni and Levenspiel, 1991).

Materials with density less than 1400 kg/m^3 and size diameter from 20-100µm, promotes fluidization, stable bed expansion when the minimum fluidization velocity is exceeded and must be sustain to achieve particulate fluidization (Anon, 2008). An example of bed material is ash from coal with no sulphur content (Gupta, 2005). Materials of density 1400-4000kg/m^3 and 40-500µm exhibit less stable bed expansion. This group were often achieved by percentage fraction of size grading .For example a bed material, may consist of 100µm at 90% and 400µm at 10% as well as 2600kg/m^3 at 30% and 1400kg/m^3 at 70% to achieve good fluidization. An example is 100- 300µm silica sand and coal powder which were used for wood chips and low ash coal-fired fluidized bed combustor. Materials of mean diameter greater than 600µm and dense particles are often used for circulating fluidization because of associated required gas velocity to overcome its pressure drop. An example was limestone used for high sulphur coal requiring sulphur retention (Rao and Parulekar, 2004). There is need to subject local materials to physical and chemical tests in selection of high quality bed materials (Damisa and Abubakar, 2007).

The objectives of the research were to:

(i) Determine the chemical composition that influences absorbent in combustor.

(ii) To obtain the various mesh size, size distribution for each bed materials and the required process technology.

(iii) Verify the dust collector system efficiency in handling local bed materials.

Materials and Methods:

Study Areas, Locations and Sample Preparation: The material samples used for this research were obtained during dry season between February-April, 2008 from different locations in Nigeria.

Ikpesi, Igarra and Ukpilla are areas near Auchi in Akoko-Edo L.G.A. of Edo state. These three areas are within geographical location of 7.5°N by 6.5°E. Obajana quarry of Jakura Marble Industries Ltd, Lokoja, also with geographical location of 7.7°N by 7°E. The climate of both areas is tropical and consists of 6 months (May-October) of wet season and 6 months (Nov.-April) of dry season. Nafada is located about 11°N by 11°E in Sudan savannah of about 8 months of dry season. Mfamosing is geographically located at about 5°N by 8.2°E and within sub equatorial climate which had high forest of about 2 months of dry season. Rock samples (15Kg each in lump sizes) were collected from 3 different locations at each stockpiles of Mfamosing limestone, Jakura marble, Igarra Calcite, Ukpilla calcite and Kaolin, Ikpesi calcite and dolomite and Nafada gypsum run-of-quarries. They were done in a zigzag order and mixed to have representative sample for each of the location. The samples were further broken manually with a sledgehammer to provide the required size acceptable to the laboratory jaw crusher.

Size Reduction, Size Grading and Process Technology:

Representative samples weighing 6kg each in three places were reduced into specific sizes by Denver laboratory jaw crusher, pulverized roll mill, ball mill and sieved at Mineral Processing laboratory, Federal University of Technology, Akure (Boore, 2008). The gape and set were adjusted to the required size. Each of the experiments were timed as well as feed and product sizes measured with specific sieve. Each of the experiments for the same sample were repeated three times and an average taken. Reduced materials products were transferred to the sieves and sieving was performed by the sieve shaker. Each product in each sieve was weighed and recorded as percentage weight retained, mesh size and initial weight.

Elemental Oxide Composition: Chemical analysis was done at analytical chemistry laboratory of the Federal University Technology, Akure (Boore, 2008). The elemental oxide compositions of the sample were determined using Atomic Absorption Spectrograph (AAS). It involves dissolving the mineral into an acidic solution. In order for the dissolution to take place completely, the mineral was ground to a fine powder of 212 μm size. This was to increase the surface area for appropriate acid usage. Generally, all elements cannot be determined by the same wet chemical method, hence, a combination such as volumetric, colorimetric, and gravimetric analysis methods were used.

Dustiness Test: Aerodynamic and dustiness test was performed using the test rig at Mining Engineering Ventilation laboratory of the Federal University of Technology, Akure (Boore, 2008). The quantity that can be lifted by suction motor, trapped by the cyclone and filter illustrate the aerodynamic properties of the gas and solid materials. The weight of recovered powder through filter all over initial weight is the dustiness of the rock sample. Its ability to expand in

bed, perform contacting function and dust available for dust collection system. Known weights of each mineral sample were placed in a container. The suction motor was switched on to suck the 100μm size sample into the cyclone and filter through pipelines. Some of the powder were trapped and dropped into the recovery container placed beneath the cyclone and filter. Each weight of the powder in the containers was weighed on an electronic weighing balance

Results and Discussions:

Table 1: Chemical Analysis of Nigerian Bed Materials

S/N	Bed Materials	CaO	MgO	SiO_2	Fe_2O_3	Na_2O	K_2O	MnO	ZnO	CuO
1	Mfamosing Limestone	55.7	0.15	1.35	0.4	17.94	6.79	0.17	1.38	8.20
2	Jakura Marble	96.7	-	0.9	0.07	-	-	0.08	1.70	0.33
3	Ukpilla Kaolin	7.7	2.35	44.3	1.45	0.26	0.43	0.04	0.30	0.30
4	Ukpilla Calcite	53.1	2.11	12.2	4.25	6.11	4.01	0.13	0.70	0.60
5	Ikpesi Calcite	55	3.25	7.0	6.27	9.59	7.79	0.11	0.85	0.76
6	Ikpesi Dolomite	39.5	11.4	4.07	8.63	11.85	8.74	0.14	0.95	2.44
7	Nafada Gypsum	12.3	13.8	2.35	3.61	13.94	15.3	15.3	0.6	0.27
8	Igarra Calcite	54.7	4.7	3.4	4.35	7.2	4.27	0.06	0.63	5.8

Gypsum was relatively softer than limestone, calcite and dolomite and not erosive as well as with little or no wear on heat surface. Gypsum doesn't catalyze nitrogen oxide formation from nitrogen contained in the coal as doe's limestone (Anon, 2008). Nafada gypsum as in tables I am 2 had less calcium oxide content and therefore, may not expand as much as in limestone and calcites.

Table 2: Bed Materials Sieve Analysis at 100μm Diameter by Cyclone, Filter and Flue Gas

s/n	Bed materials	Initial weight at suction pipe,g	Cyclone trap,%	Filter trap,%	Flue gas,%
1	Ikpesi dolomite	300	68.83	22.46	5.61
2	Nafada gypsum	453	72.56	21.83	5.96
3	Ukpilla kaolin	347	77.74	12.35	9.01
4	Jakura marble	600	75.61	17.28	7.11

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5	Ukpilla calcite	900	76.72	15.16	8.12
6	Igarra calcite	520	87.52	7.36	5.12
7	Ikpesi calcite	220	85.91	7.01	6.18
8	Mfamosing limestone	350	84.46	8.83	7.21

The particles at 100μm was effectively been trapped by the cyclone and filter. It was a suitable material for bed material in fluidized bed combustion. Limestone, calcite and dolomite are sulphur acceptor material. Ikpesi dolomite as in tables 1 and 2 has CaO and MgO that can capture sulphur to form $CaSO_4$ and $MgSO_4$. The $CaSO_4$ and $MgSO_4$ will then be drained off beneath the air distributor. At 100μm Ikpesi dolomite, Mfamosing limestone and the calcites in tables 1 and 2 are suitable but the air distributor openings design will require consideration to avoid blockage of air inlet openings due to expansion as a result of calcined limestone and calcites. Ukpilla kaolin may not be suitable due to its chemical composition although its size distribution meet requirements for bed materials.

Conclusion:

Bed materials used in fluidized bed combustion with high quality are available in Nigeria. The selection process includes size reduction of the minerals by jaw crusher, impact mill and ball mill. The materials were reduced to 100-600μm. The chemical composition was determined. Materials with less sodium and calcium oxide are preferred, to minimize the effect of expansion during calcinations in the combustor. In addition, size grading were performed using sieves and sieve shaker. The product at 100μm was subjected to dustiness test with less than 10% escapable to the atmosphere and the rest trapped by the cyclone and filter.

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