The Effect of Sawdust on the Insulating Effect of Ikere Clay as Refractory Lining

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Abstract

Refractories are sought in various industries for numerous uses. This discourse examines their necessary and compressive properties, their uses and their environment. It explores the possibility of using local clays for refractories after proper processes have been applied. The research further explores the effect of sawdust on the insulating effect of Ikere clay as refractory lining. The presence of air in these pores reduces the conductive capacity of the refractories and therefore increasing their insulating characteristics. Apart the use of sawdust to clay likewise other materials can be used such as rice husk, groundnut husk, and agricultural agro-waste. This effect was examined on the loss on ignition, thermal shock, compressive strength, bulk density, porosity, shrinkage, refractoriness, thermal conductivity of the clay. The various properties of the refractories were obtained and tested and their results discussed. An optimum one was chosen for each kind of heating environment there are (Ovens and Furnaces), and the final bricks were produced.

***Keywords**: Refractoriness, compressive properties, conductive capacity, porosity, thermal conductivity.*

Introduction

Clays are anhydrous complex compounds of aluminum (Al_2O_3) and silica (SiO_3) that exist in various proportions and contain varied amount of impurities of iron, organic matters and residual minerals (Sanni 2005).

Nigeria as a developing economy houses a lot of industries that utilize refractory material in abundance. Nigeria also has abundant mineral resources including clay. Despite the large deposits of clay in many parts of the country, local manufacturing of refractory materials for local use had been very low. Refractories are used in metal melting and heat treatment industries because of their high temperature operating conditions. It is also used in industries both as lagging and insulating material. They degenerate with time and therefore need replacement (Abifarin 1999). If the industries that use them are to remain in business, replacement must not only be produced but also must be locally sourced. Clay minerals are of secondary geologic origin i.e. they were formed as alteration products of alumino-silicate rocks in an environment in which water is present (Olusola 1998). Clay minerals are produced mainly from the weathering of feldspars and micas. They form part of a group of complex alumino-silicates of potassium, magnesium and iron, known as layer-lattice minerals. They are very small in size and very flaky in shape, and so have considerable surface area (Thring 1962).

The clays used for furnace linings in metallurgical industries are classified as refractory clays. However, the degree of refractoriness and plasticity of any clay material is often influenced by the amount of the impurities contained in them. Moreover, the ability of selecting refractory clay to withstand high temperature and resist physical and chemical corrosion determines the quality and the suitability of such material for use as furnace lining. Clays when fired, lose their chemically bonded water and plasticity at about 500°C, thus acquiring higher mechanical strength between 950° and 1,350°C as the firing temperatures progresses (Al-Amaireh 2009).

Clay refractoriness refers to its ability to resist melting at high temperature, prevent heat flow across its cross-sectional boundary layer as much as possible, maintain volume stability at high temperature (linear, area and cubical expansively must be acceptable), withstand unsteady thermal and physical shock, resist abrasion and corrosion and should have higher hot strength and be resistant to hot fluids (gases and liquids). In addition, refractory materials must be dense and porous; hence, insulating refractory clays are high porosity refractory materials with low thermal conductivity and high thermal insulating properties. They have the capability to minimize heat loss in furnaces as much as possible and maximize heat conservation to a great extent. Refractory clays consist mainly of mineral kaolinite (Al_2O_3. $2SiO_2.2H_2O$) and are broadly classified as fireclays and kaolins, depending on the constituent ratio of aluminum to silica. Consequently, refractory clays that are of the kaolinitic type contain ratio 1:2 of aluminum to silica, while fire clays that are used as refractories material contain at least 30% aluminum (Al_2O_3) and less than 1.8% (Fe_2SO_3) (Sanni 2005).

Kaolin refractory clays can be distinguished from fire clays by their whiter color, relatively coarse particles, lower plasticity and much lower impurities. The impurities in fire clays are limonite, pyrites, quartz, calcites, ferrous carbonates and some organic compounds. The organic impurities impart plasticity to the clays while impurities such as quartz and iron reduce their refractoriness. However, refractory clay material obtained from a single site cannot possess all the required properties that will make it a perfect refractory material, hence, it becomes imperative to select clays based on the physical, chemical, and thermal, analysis of samples. The selected refractory clay will have to be beneficiated with refractory clay material from other sites and be properly blended with other additives to improve their physical, thermal, and chemical properties of the final product (Nuhu and Abdullahi 2008).

A furnace is a thermal envelope and a device used for heating. It is an apparatus in which heat is liberated and transferred directly or indirectly to a solid or fluid mass place inside its enclosure for the purpose of effecting physical and chemical change on the material (Schutt and Beggs 1997). The source of heat generation for direct energy supply to furnaces are: fuel combustion as obtainable in the oxidation of fossil fuel, electrical energy due to the flow of electricity in resistance or tubular heaters, atomic fission or fusion in nuclear reactors and solar energy through focusing collectors, as applicable in solar thermal conversion devices.

This characteristic enables firebricks to be valuable in permitting rapid changes in temperature with minimal thermal losses and consequently its application in furnaces. Firebricks are actually obtained in a variety of ways, but the most popular route is by forming a mould with a mixture of kaolin, bulk clay and organic matter such as wood sawdust or rice husk in specific ratio and subjecting the mould to high temperature firing when dried. The organic content of the mould burns out when fired to high temperature, to create air voids or

Pores that further improve the insulating properties of the materials that could now be referred to as firebricks.

Thermal conductivity decreases in refractory materials as its porosity increases with the pores acting as non-heat conducting media. Porous refractories have air entrapped in them. Moreover, the porosity of refractory materials is determined by the amount of air entrapped in its pores and consequently a measure of its insulating quality. Hence, when the porosity of refractory material the high; its thermal conductivity will be low and vise versa. Therefore, the refractories used in melting furnaces, are made to have low thermal conductivities, ensure minimal heat loss and maximum heat retention, and to guarantee large temperature variation within the thermal envelope with maximum energy conversion efficiencies.

Chesti (1986) defined refractories as "materials that are hard to fuse" and classified them as materials that can withstand high temperatures, resist the action of corrosive liquids and withstand the thermal stresses imposed by dust-laden currents of hot gases or vapors without losing their insulating properties and wall rigidity. Refractory materials are therefore utilized for the construction of furnaces, crucibles, and other materials that are subject to high temperature operations in order to ensure perfect resistant to heat loss and to overcome the corrosive action of gases and slag that may be present in the plant. High temperature operations are usually involved in almost all operations dealing with the treatment of ores and in the processing of metallurgical, chemical, ceramic, and foundry raw materials; thus making the use of refractories materials inevitable.

Materials and Methods

Equipment and Materials

The experiments were performed at the mineral processing laboratory of the Federal University of Technology Akure. The equipments used are Pulverizing Machine, Ball Machine, and Sieve Shaker. The materials used in the course of this project are; Ikere clay which was collected from Ikere Ekiti, Ekiti State, Saw dust which collected from Akure metropolis.

Sample Preparation

The collected clays were sun dried for some days and grounded using ball mill and pulverizing machine. 150μm mesh size was used to sieve the grounded sample. The sieved sample was mixed with different proportion of sawdust and water. The mixture were moulded into cylindrical shape, dried, fired and weighed.

Results and Discussion

Table 1 discussed about different mixtures of the sample at different percentage of the materials. Thereafter different analyses were conducted on the loss on ignition, thermal shock, compressive force, bulk density, porosity, shrinkage, refractoriness and thermal conductivity. The results were shown in the tables below from the results got sample E out of other samples had the suitable material has with the compositions 75% Ikere kaolin, 20% sawdust and 5% water.

Table1. The different mixtures of the samples.

Sample	% Ikere kaolin	% Sawdust	% Water
A	95	0	5
B	90	5	5
C	85	10	5
D	80	15	5
E	75	20	5
F	70	25	5

Table 2. The Loss on ignition of the different sales at 900°C.

Sam -ples	Initial weight	Final weight (g)	Weight different (g)	%weight loss
A	97	87.01	9.99	10.29
B	95	80.00	15.00	15.75
C	92	72.74	19.26	20.67
D	92	72.06	19.94	21.83
E	89	68.20	20.80	22.24
F	90	70.35	19.65	21.83

Table 3. The loss on ignition of the different samples at 1,200°C.

Sam ples	Initial weight	Final weight (g)	Weight different (g)	%weight loss
A	97	80.00	17.00	17.52
B	95	65.19	29.81	31.37
C	92	60..29	31.71	34.46
D	92	55.02	36.98	40.19
E	89	45.00	44.00	49.43
F	90	50.00	40.00	44.44

Table 4. The average thermal shock/spalling resistance.

Samples	Average number of cycles
A	28
B	26
C	24
D	26
E	25
F	23

Table 5. The compressive force needed to crumble the samples.

Sam-ples	Area (cm^2)	Compres-sivestrength (kg/cm^2)	Compressive force(kg)
A	13.65	6.5	88.73
B	13.65	5	68.25
C	13.65	6	81.90
D	13.65	6.5	88.73
E	13.65	8	109.20
F	13.65	2.5	61.42

Table 6. The bulk density of the various samples.

Sam-ples	Weight of fired samples	Bulk volume (cm^3)	Bulk density (g/cm^3)
A	49.30	50.19	0.98
B	47.00	44.30	1.06
C	40.40	42.40	0.95
D	52.76	55.01	0.96
E	41.89	38.01	1.18
F	42.52	35.95	1.18

Table 7. The degree of porosity of the various samples.

Sampl es	Dry wt.t	Wet wt	Wt. differ-ent	Bulk density	% Poro sity
A	49.3	72.97	23.67	0.98	47
B	47.0	64.02	17.02	1.06	38
C	40.40	62.04	21.64	0.95	51
D	52.76	76.37	23.61	0.96	43
E	44.30	66.03	21.73	1.10	54
F	42.54	60.67	18.13	1.18	50

Table 8. The firing shrinkage at 1200 ^oC of the samples.

Sam ples	Initial length (Lo)	Final length (Lf)	Differ-ent in length (ΔL)	%shrink-age $\frac{\Delta L \times 100}{Lo}$
A	10.9	10.10	0.80	7.33
B	10.9	10.00	0.90	8.06
C	10.9	10.20	0.70	6.42
D	10.9	10.00	0.90	8.26
E	10.9	10.22	0.68	6.24
F	10.9	10.21	0.69	6.33

Table 9. The amount of heat passing through the sample at 1200^{0}C (Thermal Conductivity)

Y (min)	X	A	B	C	D	E	F
1	T_1	31	27	27	31	27	32
	T_2	40	40	30	40	40	50
2	T_1	31	28	27	32	27	36
	T_2	41	78	80	45	80	80
3	T_1	31	31	30	33	30	38
	T_2	60	124	160	110	120	100
4	T_1	34	39	34	35	32	40
	T_2	120	150	220	210	132	160
5	T_1	36	49	38	39	36	43
	T_2	160	180	350	310	160	240
6	T_1	39	61	42	43	40	48
	T_2	210	405	450	405	180	280
7	T_1	42	63	46	48	45	50
	T_2	250	450	560	500	200	360
8	T_1	46	65	50	54	50	52
	T_2	390	600	640	620	680	410
9	T_1	50	68	56	59	65	55
	T_2	570	700	710	720	790	520
10	T_1	53	70	63	64	66	61
	T_2	870	990	900	910	850	890
Z		0.10	0.11	0.11	0.11	0.12	0.09

Table 10. The amount of heat passing through the sample at 600^{o}C (thermal conductivity).

Y (min)	X	A	B	C	D	E	F
1	T_1	31	27	27	31	27	32
	T_2	40	40	30	40	40	50
2	T_1	31	28	27	32	27	36
	T_2	41	78	80	45	80	80
3	T_1	31	31	30	33	30	38
	T_2	60	124	160	110	120	100
4	T_1	34	39	34	35	32	40
	T_2	120	150	220	210	132	160
5	T_1	36	49	38	39	36	43
	T_2	160	180	350	310	160	240
6	T_1	39	61	42	43	40	48
	T_2	210	405	450	405	180	280
7	T_1	42	63	46	48	45	50
	T_2	250	450	560	500	200	360
Z		0.28	0.23	0.27	0.16	0.37	0.28

Key: samples (x), time (y), thermal conductivity (z).

The Choice of Sample E

From Table 1, sample E has 75% kaolin, 20% sawdust and 5% water. The fired weight of sample E is the least of all samples as additional sawdust (i.e., sample F) gave increased fired weight (i.e., 50.00) as shown in Tables 2 and 3 show that both sample E and F are lighter in weight reflect that very high compressive force up to 109/mm^2 will be required to break the refractory sample A.

Also the percentage porosity of sample E is the higher recorded during the experiment (Table 7). This is also an advantage in refractory lining material selection. It is also noted that sample E among other did not lose its refractoriness at up to 1,200^{o}C.

In conclusion, sample E among all samples selected reflect the result for refractory lining which is also confined by its thermal conductivity across sample shown in Tables 9 and 10.

Conclusion

From the research carried out on addition of sawdust to a clay sample, a conclusion was reached that pores reduce the conductive capacity of the refractories and therefore increase their insulating characteristics after tests were conducted on its properties, like porosity, thermal conductivity, and linear shrinkage bulk density of the clay sample. If other agro-wastes are used in the right proportions and proper tests are carried out, it would serve even better.

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