DETERMINATION OF WATER ABSORPTION RATE OF PALM KERNEL SHELLS AS AN ALTERNATIVE PORE AGENTS IN INSULATING REFRACTORY BRICKS

Clement Etim Ekong
Department of Fine and Industrial Arts
University of Uyo, Uyo
Akwa Ibom State, Nigeria.
domosehekong@yahoo.com

Abstract

Various organic pore agents are used for the production of insulating refractory bricks (IRB). Most times, the deficiencies of the respective pore agents appear to be ignored by the makers of the bricks, and the users. Sawdust, for instance, which is about the most commonly used organic pore agent is known to have high water absorption rates. This is in addition to the inability of the user to have it from one grade of wood-hard wood which is preferred. These factors amount to various drawbacks in the insulating refractory bricks produced with it. In order to curb this problem, this study identified palm kernel shells (PKS) as a potential alternative pore agent in IRB bodies. The focus of the work was on the water absorption rate of PKS. The study employed studio experimentation method. It showed that the water absorption rate of PKS is insignificant and, therefore, is recommended for use as pore agent in insulating refractory bricks.

Introduction

The consequences of organic material/hydrocarbon additives on the properties of insulating refractory bricks (IRB) when the bricks are fired at high temperature are enormous. These include decrease in density, and creation of pores. Thus, when the bricks containing hydrocarbon are fired at high temperature, the particles of the organic materials are burnt off leaving pockets of air. This changes the composite insulating refractory bricks (IRB) to insulating refractory bricks with myriads of pores. The density on its part is decreased with increase in the organic material content of the insulating refractory bricks body. The introduction of voids (pores) which contain stagnant air in the erstwhile dense composite body is in consonance with micro porosity and Knudsen effects which inhibit thermal conductivity in bodies.

Various conventional organic materials abound which are used as pore agents in insulating refractory bricks. These organic materials have different advantages and disadvantages. The most abundant and most commonly used organic pore agent, sawdust is known to have very high water absorption rate. Therefore, insulating refractory bricks made using sawdust as pore agent take relatively long time to dry (Norsker, 1987:np; Okonkwo, 1988:1409; Kashim, 1999:67). Besides, sawdust is always a mixture of a variety of woods since it is usually taken from the lot at saw mill refuse dumps. Thus, sawdust from hard wood alone is not always available. Therefore, it is always used as it is found even though it is known that sawdust from hard wood produces smaller pores than sawdust from soft wood (Norsker, 1987:np). The study is, therefore, set to identify a substitute organic material that can be used as pore agent in the production of insulating refractory bricks; an organic material that would enhance quick setting with negligible or no deformations during production but burn-out to produce pores in fired insulating refractory bricks.

Pore Agents in Insulating Refractory Bricks

Pores in insulating refractory bricks are either created by physical or chemical process, or both. The physical process involves the addition of organic fillers which burn out on firing to produce pores. In this process, insulating refractory bricks are formed by mixing a refractory clay or clays and a highly refractory aggregate with granular organic fillers which are combustible pore forming agents. The refractory aggregate can be alumina, alumina silica, magnesia or zirconium. The conventional organic fillers beside sawdust include rice husk, foamed Polystyrene or coke (Horie et al, 2000:1; Ugheoke et al, 2009:3).

Zarkin (1990:15) sees fillers as coarse materials added to clay bodies to strengthen and open up the body. On his list of organic fillers useable for this besides sawdust are coffee ground, chopped nylon and foamed pellets. All of these are burnt-out during firing leaving voids in the fired body. The chemical process involves re-acting the aggregates to form bubbles. In this process, the pores in insulating refractory bricks are introduced by the addition of naphthalene or other substances that react chemically to form bubbles. It can also be done by the addition of diatomaceous earth (Horie et al, 2000:3).

These pore agents have their respective advantages and disadvantages. Formed polystyrene, for instance, absorbs less water. Therefore, less amount of water is needed when it is used. The shrinkage is equally low when fired and reheated. It gives high strength and low bulk density. Foamed polystyrene is low in calorific content and therefore burns easily. Although foamed polystyrene absorbs relatively small amount of water, during casting, the amount of water tends to be higher than most moulding methods. The product displays high dry shrinkage. Unless gypsum moulds are used, the forms cannot be removed until the moulds are completely dried (Horie et al, 2000:5). In addition, the formed shape will be trapezoidal when dehydrated. Thus, the products will be unstable in shape. Though the slip in the mould could be stabilized with gypsum, cement, size or resin, the large amount of these stabilizers that would be required would alter the chemical composition of the products. This would, therefore, interfere with drying and firing steps and would result in long and incomplete hardening of slip (Horie et al, 2000:5).

The Need for Pores in Insulating Refractory Bricks

The transfer of heat by conduction occurs from one solid to another when they are in direct contact with one another. Equally, conduction of heat from one part of a solid to the other is facilitated when the material is dense. The denser a material, the closer its atoms are. That means the transfer of heat energy from one atom to the next is more rapid when the atoms are closer. In dense materials, kinetic energy atoms and molecules bump into their neighbours and increase the neighbours' energy. The increase in energy causes its flow "through materials and from one material to another" (Kurtus, 2006:2). The resultant energy transformation of the combined micro-porosity and Knudsen effects loosens up the otherwise dense body. They cause the materials to be porous. They also cause the kinetic energy atoms and molecules to be inactive. This inactivity inhibits the conduction of heat through the affected body; in this case, the insulating refractory brick.

Micro-porosity describes the character of a material(s) with very tiny pores. The creation of myriads of tiny pores in a material causes it to be porous. The pores so created in a solid either by chemical process or by the introduction of combustible materials entrap air. These air pockets enhance porosity. Porosity lowers the density of a solid. This brings about high thermal resistivity of the solid. Effective insulating materials require relatively low thermal conductivity in order to reduce the co-efficiency of heat transfer. Thus, reducing the pore sizes to nanoscopic level would increase the collisions between the gas molecules and the pore walls, that is Knudsen effect, and such an effect could be potentially used to reduce thermal conductivity (Raman et al, 2009:1). He adds that for effective thermal insulation, materials with high porosity (≥ 90%) and nanoscopic (˜100 nm) pores are required. This means that porosity in these materials should be very high. This corroborates Maore et al (2009:1) averment that porosity is the major determinant of low thermal mass which is important for heat energy efficiency.

Most stagnant gases, including air, are poor conductors of heat. This low thermal conductivity of stagnant air is what enhances insulation as it has been identified as one of the best insulating materials (American Society of Heating, Refrigerating and Air-conditioning Engineers – ASHRAE, 2010:1). This is so because the gas molecules of the entrapped air experiences Knudsen effect. This effect eliminates the exchange of energy in the entrapped air, thereby hindering heat transfer. This lowers the overall thermal conductivity of the solid (NanoPore, 2009:1). The lack of exchange of energy, Knudsen effect, is as a result of the motionless nature of the air in the pores as air and water can only transfer heat by convection via their motion (Kurtus, 2006:3). It is of little wonder, therefore, as most conductive barriers often incorporate a layer or pockets of air to reduce or slow heat transfer. Thus, conductive heat transfer is hindered by the presence of air filled spaces rather than the materials itself.

Similarly, Landis (2009:3) avers:

> Air offers resistance to heat flow a rate about 15,000 times higher than that of a good thermal conductor such as silver, and about 30 times higher than that of glass. Typical insulating materials, therefore, are usually made of non-metallic materials and are filled with small air pockets. They include magnesium carbonate, cork, felt, cotton bathing, rock or glass wool, and diatomaceous earth.

The reduction of thermal conductivity of a material, therefore, hinges on the amount of dry stagnant air content of the material. This means the material needs relative higher number of tiny pores. Undoubtedly, the insulating properties of most insulating materials are determined by the amount of gas held within the material and the number of air pockets. The larger the number of tiny pores, the better the material is. In the affirmative, American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE, 2010:2) observes that "the higher the number of cells (which can maintain the gas stagnant) and the smaller their size, the lower the thermal conductivity of such insulating material. These cells should not be interlinked as this will allow convection of heat".

Source of Palm Kernel Shells (PKS)

Palm kernel shells (PKS) are derived from oil palm. Oil palm, botanically known as *elaeis guineensis* is native to West Africa and widespread throughout the tropics (Encarta, 2009). It is an African Tree (Encyclopaedia Britannica, 2011). In Nigeria, the palm is found in abundance in the South South and South East zones. The oil palm yields a cluster of oval red, orange or yellowish fruits. Its mature fruit is between 3cm and 4cm long.

Oil palm is useful in a variety of ways. Its various parts are used as pharmaceuticals, lubricants, food, animal feed, cosmetics, building material, fuel, household utensils to mention a few. There is virtually no part of the palm that is not useful. The most popularly known use of the oil palm, however, appears to be the area of red oil extracted from its fruits. Next to this is the palm kernel oil which is described in Encarta (2009) as the more valuable oil. The next is the cake left after this oil is extracted which is used as animal feed.

In view of the multi-value of the oil palm and its abundance in the South-South and South-East regions of Nigeria, the shells that hold the kernel were tested and analyzed to ascertain their physical and chemical properties, and general behaviour. This was to help in the prima fascia assessment of the possibility of using it in an insulating refractory bricks body as a pore agent.

Methodology

Palm kernel shells (PKS) obtained from a palm oil mill at Afaha Itak in Ikono Local Government Area of Akwa Ibom State was crushed in a hammer mill and the particle sizes were graded into 1mm, 2mm, 3mm and 4mm. Water absorption tests were carried out for each grade of PKS. Water absorption test was performed by a 24 hour immersion in cold water. A known mass of 20g of each particle grade of PKS was preconditioned by drying in a test kiln at 110°C. This was to ensure total water loss in the samples. After they were allowed to cool at room temperature, each particle grade was weighed and the dry (initial) mass was recorded. Each of the preconditioned particle grades was immersed in cold water and allowed for 24 hours in room temperature. Thereafter, the samples were collected in a 75 micron mesh. This was in order to get rid of excess water. The residue was weighed and the new mass recorded against the initial mass. The percentage water absorption for each sample was then calculated using the formula.

$$\frac{\text{Mass of water absorbed}}{\text{Initial mass of substance (PKS)}} \times \frac{100}{1}$$

Results and Discussion

Table 1: Absorption rate of Palm Kernel Shells (PKS)

Material/particle size	**Initial mass (g)**	**New mass (g)**	**Mass of H_2O absorbed (g)**	**H_2O absorbed (%)**
PKS (1mm)	20	29	9	45
PKS (2mm)	20	22	2	10
PKS (3mm)	20	25	5	25
PKS (4mm)	20	25	5	25

The result of absorption tests is as presented in table 1. The water absorption tests showed low percentage absorbency. The high absorption rate obtained from 1mm grade of palm kernel shells is, perhaps, due to its fibre content since this was not present in other grades. The results as shown in table 1 indicate that the larger the particle sizes of PKS, the lesser the amount of water absorbed.

The most interesting aspect of the result is that PKS does not absorb water above 45%. The 1mm grade which absorbs water above 45% is enhanced by its high fibre contents. Fibre was high in the grade because they could not pass through the mesh. The 2mm grade which had about the most ideal water absorption had just 10%, while 3mm and 4mm grades had 25% each. The relative low absorbency of PKS, therefore, makes it a potential alternative to saw dust or a potential co-pore agent in a body mixture for insulating refractory brick bodies since saw dust is known to take relatively long time to dry due to the high amount of water it absorbs (Norsker, 1987; Okongwu, 1988:1409; Kashim, 1999:67).

Findings

From the results obtained, the findings can be presented as follows:

1. Palm kernel shells (PKS) have low water absorption. This property would allow for minimal use of water of plasticity in the production of insulating refractory bricks. The presence of little quantity of water in the wet brick would reduce drying time, thereby quickening the production process.

2. Since palm kernel shells (PKS) have very low water absorption rate, and allow for minimal use of water of plasticity in the body preparation, shrinkage would be reasonably reduced. Thus, insulating refractory bricks produced using PKS as pore agents would record little or no change in volume due to water loss.

3. Due to hard and seemingly crystalline nature of palm kernel shells (PKS) which does not allow for volume change due to compression; there would be impressive stability in the pore volume created in the bricks. That is, since there is no change in volume of PKS due to compression, the pore volume created in the brick would equal the particle size of the PKS used in the composition.

4. As the palm kernel shells (PKS) are not readily compressed to a smaller volume, there is greater tendency for the particles to be independent of one another when used in body composition. Since the pore created is dependent on the PKS initial particle size, there is relative possibility of predetermination of pore size of insulating refractory bricks. The independence of the particles is bound to create independent tiny pores, and there would be less or no linkages of the pores. This would ensure stagnation of the entrapped air. This would enhance the effectiveness of the insulating refractory bricks.

5. The strength of the insulating refractory bricks would be enhanced as a result of the pore independence in the bricks produced with palm kernel shells (PKS) as the pore agents. This would be due to the lack of interdependency of the pores in the composite brick. Thus, network of pores would not be experienced in bricks produced using PKS.

6. High amount of fibre in organic pore agents enhances its absorbency.

Conclusion

It is obvious from this investigation that palm kernel shells (PKS) would make good alternative pore agents in insulating refractory bricks. Its hardness and low water absorption have the potentialities of producing controlled size and independent pores. It would also enhance the creation of micro pores in insulating refractory bricks. This study, therefore, recommends its use as pore agent in insulating refractory bricks.

References

American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) (n.d) Comparison of Thermal Conductivities of R – 11, dry air, water vapour, water and ice within an insulating material. Retrieved May 20, 2010, from http://www.fao.org

Ekong, C.E. (2012). Formulation of Clay Bodies Using Local Materials for Insulating Refractory Bricks. Ph.D Thesis. Fine and Applied Arts Department, Delta State University, Abraka.

Horie, E.; Takeo, S., Shinichiro, O., Hideo, H. & Naoki T. (2000) *Process for* *making heat insulating firebricks*. Bizarre Patents. Retrieved July 21, 2009 from http://www.patentstorm.us

-------------------(1981) *Process for Making Heat Insulating Firebricks*. USA Patent. Retrieved July 21, 2009 from http.//www.freepatentsonline.com

Kashim, I.B. (1999) "Manufacturing of efficient kilns from locally derived refractory materials in Nigeria" in *Journal of Industrial Design & Technology*. 1(1), pp 64 – 70.

Kurtus, R. (n.d.) "Thermal Insulation Prevents Heat from Escaping." Retrieved April 29, 2006 from http://www.school-for-chanpions.com

Landis, F. (2009) *Insulation*. Microsoft ® Encarta ® 2009 [DVD]. Redmond, WA: Microsoft corporation.

Maore, M., Charles C., Chris, H. & Robert B. (n.d.) "High temperature insulating refractories: technical, economic, health & safety, and environmental issues." Retrieved December 7, 2009 from http://cat.inist.fr/?amodel

*Nanopore "*Thermal Insulation." (2008) Nanopore. Retrieved July 7, 2009 from http://www.nanopore.com/thermal html

Norsker, Henrick (1987) "The self-reliant potter: refractories and kilns." Retrieved July 25, 2009 from http://nzdl.sadl.uleth.ca/cgi-bin/library.cgi?e

"Oil Palm" Microsoft Encarta ® 2009 (DVD), Redmond, WA: Microsoft Corporation, 2008.

Oil Palm (2011). Encyclopedia Britannica. Ultimate Reference Suite. Chicago. Encyclopedia Britannica.

Okongwu, D.A. (1988) Effects of additives on the burnt properties of clay bricks. *American Ceramic Society Bulletin*. 67 (8) 1409 – 1411.

Raman, V.I., Schadler, V. & Palmese, G.P. (2005) "Designing nanoporous polymers using sol-gel techniques for permeation membrane and thermal insulation applications." Retrieved July 29, 2009 from http://aiche.cofex.com/aiche/2005/techprogram/p25651.HTM

Ugheoke, B.I., Onche, O.O., Namessan, O.N., & Asikpo, G. "Property Optimization of kaolin-rice husk insulating fire-bricks." (n.d.) Retrieved July 17, 2009 from http://lejpt.academicdirect.org

Zarkin, R. (1990) *Ceramics: Mastering the Craft*. Wisconsin: Krause.