Project Title

Design, Fabrication and Installation of Multi Air Cyclone System for the Beneficiation of Kaolin Clay.

Executive Summary

The air cyclone is a commonly used piece of equipment that makes use of the centrifugal and gravitational fields to separate particles in gaseous streams. Cyclone can be used to separate almost any phase from another phase, and sometimes to classify particulates. Design and fabrication of air cyclone for kaolin beneficiation has to be carried out for effective performance. A cyclone of 0.131m body diameter (D_c) will be designed based on a critical particle size diameter (d_{pc}) of 2.5µm and particle density of 2610kg/m^3, this will be fabricated and installed for the beneficiation of kaolin mineral that will be used for production of paint. This kaolin mineral is abundant in Nasarawa State. At the end of this research work, the following research problems are expected to be reduced to minimal; kaolin clay has an inherent impurities that affect its usage, kaolin as a solid mineral has not been properly harnessed in Nigeria, as a result of unavailable equipment to beneficiate it. Design, Fabrication and Installation of Multi Air Cyclone for the Beneficiation of Kaolin Clay is expected to cost about **₦6,020,000.00** (Six million, and twenty thousand naira only).

Introduction

Cyclones are simple devices, which cause the centrifugal separation of materials in a fluid stream. They have no moving parts and are cheap compared to other separation devices (Zhiyiet al., 2014). There are two types of cyclone; air cyclone and hydro cyclone. Air cyclones are by far the most common type of gas-solid separation device used in diverse industrial processes while hydro cyclone are used for liquid-solid separation (Karagozetal., 2013). Their primary disadvantage is that they have relatively low collection efficiency for particles below about 15µm (Zhao and Su, 2010). Cyclone can be used to separate almost any phase from another phase, and sometimes to classify particulates. One of the reasons for the wide variety of applications of cyclones is due to the fact that they are easy to inspect, maintain and fabricate, relatively economical to operate, can be used at high temperatures, produce a dry product and can be adapted to a wide range of operational conditions.

The air cyclone is a commonly used piece of equipment that makes use of the centrifugal and gravitational fields to separate particles in gaseous streams. These make it to be the most common type of gas-solid separation device used in diverse industrial processes. It can be used to separate major impurities in kaolin such as quartz. Kaolin deposits generally contains relatively great amounts of mineral impurities (Stefan *et al.*, 2011). The presence of these minerals has a negative effect upon the application of the clay. There are limited specifications of the maximum amount of Fe_2O_3 and TiO_2 permitted for the clay used in paper and ceramic industry. The impurities in kaolin such as iron oxides/ hydroxides and titanium minerals- rutile and mica need to be removed or drastically reduced to improve the quality of the kaolin (Stefan *e tal.*, 2011)

Kaolin is one of the most abundant solid minerals in Nigeria and its uses are numerous e.g. paint production, paper production, adsorbent in pharmaceutical industries etc. (Gonzalez *et al.*, 2007). Design of air cyclone for the beneficiation of kaolin will help in improving the level of processing of the clay in this country, since every application requires certain level of purity.

Literature on the researches carried out on air cyclone system shows that the yields obtained on the past researches in the use of single air cyclone are generally low and economically not viable (Audu, 2012).Hence the need for further research on a cyclone multiple stage pilot plant for kaolin clay beneficiation to obtain high yield.

Objective(s) of the Study

The aim of this research is to design and construct a multi-stage air cyclone system for kaolin beneficiation. The specific objectives are as follows:

(i)To study the available software on air cyclone deign for kaolin beneficiation.

(ii) To design multi-stage air cyclone systems.

(iii) Fabrication of the designed air cyclone systems.

(iv) Beneficiation of kaolin using the fabricated cyclone systems.

(v) Analysis of the product and compare it to the raw kaolin.

Literature Review

Mechanical description of cyclone separator

Cyclones consist of a vertical cylinder with a conical bottom. They have no moving parts, and pumping the fluid tangentially into the stationary cone –cylindrical body produces the essential whirling motion. The cylindrical part is closed at the top by a cover, through which the liquid overflow pipe, known as the vortex finder, extends some distance into the cyclone body. It is necessary that the end of the vortex finder extend below the feed inlet to reduce premature exist of the overflow. Located near the top cover is either a circular or rectangular feed opening where fluid enters the cyclone through a hole in the apex of the cone. The inability for all the fluid to leave at the underflow outlet assist the inward migration of some of the fluid from the external spiral. An increase in inward migration occurs, closer to the cone apex and the fluid in this migratory stream reverses its vertical direction and flows upwards, to the overflow outlet (Faulkner, 2007).The flow pattern is shown in Figure 1.

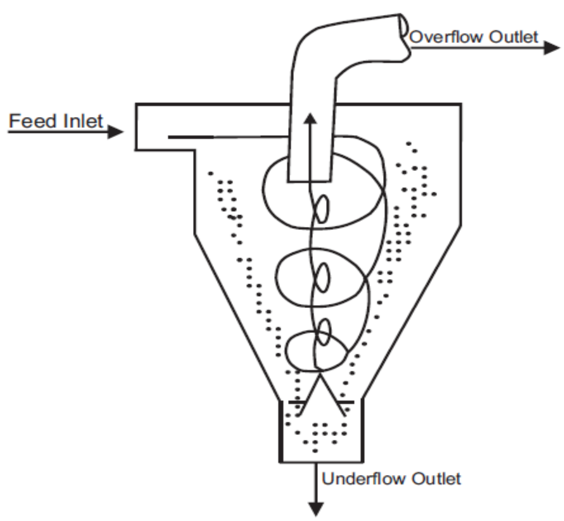

Figure 1: Schematic diagram of a typical cyclone separator.

Operating principle of cyclones

The gas or liquid stream is injected at high velocities through the inlet pipe, which is positioned tangentially to the body of the cyclone. The shape of the cone induces the stream spin, creating a vortex. Larger or denser particles are forced outward to the walls of the cyclone where the drag of the spinning air as well as the force of gravity causes them to fall down the sides of the cone into an outlet. Meanwhile, the lighter and/or less dense particles as well as the gas or liquid medium exit through the top of the cyclone through the low pressure centre. The separation process in cyclones requires a steady flow. Cyclone separators are customarily operated with the top and bottom open to the atmosphere so that there is no pressure difference between the two.

Sizing and selection

There are many sizes and types of cyclone separators available. The cyclone geometry available are Lorenz 1, Lorenz 2 and Lorenz 3 and many others but Lorenz 1 is still most preferable. They are generally of two main class irrespective of the type, namely; axial and tangential. They both operate on the same principles, however, in the axial flow cyclones; the material enters from the top of the cyclone (as shown in Figure 2.2a) and is forced to move tangentially by a grate at the top. In tangential cyclones, the material enters from an inlet on the side (as shown in Figure 2.2b) which is positioned tangentially to the body (Hsiao etal., 2011).

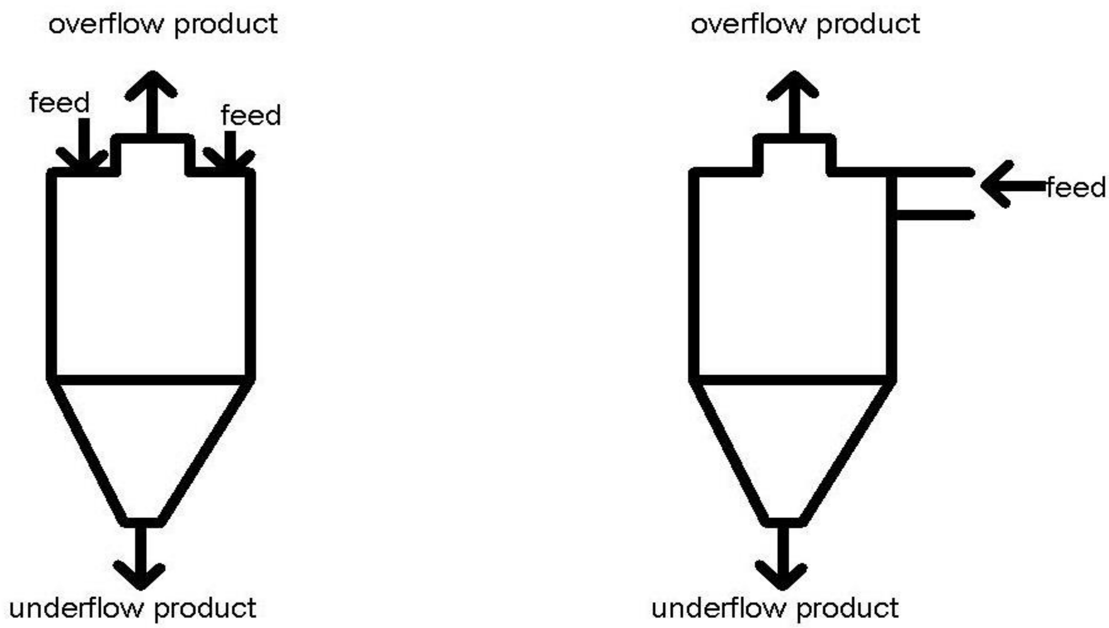

Fig.2a: Schematic view of an axial inletFig.2b:Schematic view of a tangential inlet

Cyclone configuration

The sections of cyclone separators are manufactured in varying proportions of the body diameter. Some commonly used cyclones are LD (body length = diameter) 1D3D (cone length = 3 diameter) and 2D2D (body length and cone length = 2 diameter). The efficiency of cyclone separators is dependent upon the cyclone diameter and the pressure drop between the inlet and outlet of the cyclone (Hsiao etal., 2011).

Effect of varying cyclone design parameters

According to Svarovsky(2009), for the efficiency of a cyclone to be increased the following changes are made:

(i) Reduce the cyclone diameter
(ii) Reduce the outlet diameter or increase the body length

However, to increase the capacity of a cyclone the following needed to be done:

(i) Increase the cyclone diameter
(ii) Increase the inlet diameter

(iii) Increase the outlet diameter or increase the body length

Increase in separation efficiency

(i) High capacity

(ii) decrease the underflow to throughput ratio

(iii) More concentrated underflow

(iv) Cleaner overflow

Another method to improve efficiency with high capacity load is to have sequential cyclone separators of varying size, the first cyclone may separate larger particles and the second separator may be used to separate smaller particles (Zhao and Su, 2010), for example the combination of 2D2D cyclone followed by 1D3D cyclone was very efficient in reducing total emission (Columbus, 1993)

CLAY

Clay is a fine-grained soil that combines one or more clay minerals with traces of metal oxides and organic matter. Geologic clay deposits are mostly composed of phyllosilicate minerals containing variable amounts of water trapped in the mineral structure. Clays are distinguished from other fine-grained soils by differences in size and mineralogy (Silts, which are fine-grained soils that do not include clay minerals, tend to have larger particle sizes than clays. There is, however some overlap in particle size and other physical properties, and many naturally occurring deposits include both silts and clay (Gonzalez et al., 2007).The distinction between silt and clay varies by discipline. Geologists and soil scientists usually consider the separation to occur at a particle size of 2 µm (clays being finer than silts). Colloid chemists use 1 µm. Geotechnical engineers distinguish between silts and clays based on the plasticity properties of the soil, as measured by the soils' Atterberg limits. ISO 14688 grades clay particles as being smaller than 2 µm and silts larger (Maguire et al., 2002).

FORMATION OF CLAY

Clay minerals typically form over long periods of time from the gradual chemical weathering of rocks, usually silicate-bearing, by low concentrations of carbonic acid and other diluted solvents. These solvents, usually acidic, migrate through the weathering rock after leaching through upper weathered layers. In addition to the weathering process, some clay minerals form by hydrothermal activity. Clay deposits may form in place as residual deposits in soil, but thick deposits usually form as the result of a secondary sedimentary deposition process after they have been eroded and transported from their original location of formation. Clay deposits are typically associated with very low energy depositional environments such as large lakes and marine basins.

Primary clays, also known as kaolin, are located at the site of formation. Secondary clay deposits have been moved by erosion and water from their primary location.

GROUPING OF CLAYS

Depending on the source, there are three or four main groups of clays: kaolinite, montmorillonite-smectite, illite, and chlorites. Chlorites are not always considered clay, sometimes being classified as a separate group within the phyllosilicates. There are approximately 30 different types of "pure" clays in these categories, but most natural clays are mixtures of these different types, along with other weathered minerals. Clays are categorized into six groups by the U. S. Bureau of Mines. The categories are kaolin, ball clay, fire clay, bentonite, fuller's earth, and common clay and shale (Stefan et al., 2011).

CLAY PROCESSING DESCRIPTION

Clay is defined as a natural, earthy, fine-grained material, largely of a group of crystalline hydrous silicate minerals known as clay minerals. Clay minerals are composed mainly of silica, alumina, and water, but they may also contain appreciable quantities of iron, alkalis, and alkaline earths. Clay is formed by the mechanical and chemical breakdown of rocks (Virta and Robert, 2012).

KAOLIN

Kaolin, or china clay, is defined as a white, claylike material composed mainly of kaolinite, which is a hydrated aluminum silicate ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$), and other kaolin-group minerals. Kaolin has a wide variety of industrial applications including paper coating and filling, refractories, fiberglass and insulation, rubber, paint, ceramics, and chemicals.

BALL CLAY

Ball clay is plastic, white-firing clay that is composed primarily of kaolinite and is used mainly for bonding in ceramic ware, primarily dinnerware, floor and wall tile, pottery, and sanitary ware.

FIRECLAY

Fireclays are composed primarily of kaolinite, but also may contain several other materials including diaspore, burley, burley-flint, ball clay, and bauxitic clay and shale. Because of their ability to withstand temperatures of 1500°C (2700°F) or higher, fireclays are generally are used for refractory or to raise vitrification temperatures in heavy clay products.

BENTONITE CLAY

Bentonite is clay composed primarily of smectite minerals, usually montmorillonite, and is used largely in drilling mud, in foundry sands, and in palletizing taconite iron ores.

FULLER'S EARTH

Fuller's earth is defined as a nonplastic clay or claylike material that typically is high in magnesia and has specialized decolorizing and purifying properties. Fuller's earth, which is very similar to bentonite, is used mainly as absorbents of pet waste, oil, and grease.

COMMON CLAY AND SHALE

Common clay is defined as a plastic clay or claylike material. Shale is a laminated sedimentary rock that is formed by the consolidation of clay, mud, or silt. Common clay and shale are composed mainly of illite or chlorite, but also may contain kaolin and montmorillonite.

HISTORY OF KAOLIN

Kaolin is a relatively pure, white firing clay composed principally of the mineral kaolinite $Al_2SiO(OH)_4$ but containing other minerals and minor amount of impurity mineral such as quartz SiO_2, rutile (TiO_2) and hematite (Fe_2O_3). Kaolin is a corruption of the Chinese "kauling" which means "high ridge", the name of a hill near Jauchan Fu, China, where the material was obtained centuries ago. Kaolin is the rock mass which is composed essentially of a clay material that is low in iron and usually white, near white, or colored depending on the association impurities from the source. The kaolin forming clays are hydrous aluminum silicates of approximate composition $2H_2O.Al_2O_3.2Sio_2$ and it is believed that other bases if present represent impurities or absorbed materials. Kaolinite is the mineral that is predominantly present in most kaolin.

Kaolinite mineral

Kaolinite is amongst the ubiquitous clay minerals found in soils sediments, sedimentary rocks and hydrothermal deposits. The clay minerals are essentially hydrous aluminum silicates with magnesium or iron proxing wholly or partly or the aluminum is presents as essential constituent in some of them. Some clay is composed of single clay mineral while others contain a mixture. In addition to the clay minerals some clays contains varying amount on so-called non-clay minerals of which quartz, feldspar, calcite, pyrites and mica are major examples. Also many clay materials contain organic matter and soluble salts which may have been entrained in the clay at the time of accumulation or may have developed as a consequence of weathering or alteration processes e.g. the oxidation of pyrites to give sulfates before frequently necessary to wash out the soluble salts before other attributes of the clay are studied. Common water soluble salts formed in clays are chlorides, sulfates and carbonates, aluminum and iron.

Methodology

Summary of the Method for kaolin beneficiation using multi stage Arrangement

The raw kaolin from Nasarawa State will be dried and ground to a powdered form. The parallel arrangement of the air cyclone rig will be test run using the ground raw kaolin. Two products will be obtained for every cyclone i.e. the underflow product and the overflow product. The overflow product is the desired product. The feed, the underflow product and the overflow products of the three cyclone will be collected and taken for particle size analysis. Figure 3 is a simple block diagram showing the multi stage cyclone arrangement. The flow chart is presented in Figure 3.

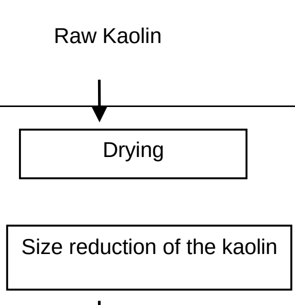

Figure 3: Steps involved in the beneficiation of kaolin using multi stage cyclone system
Results (Expected outputs/Results)
A beneficiated kaolin clay product that is free of quarts (a major impurity in kaolin)
Work Plan/Time Frame

Description of Activity	**Duration (12 months)**
Research design Literature review and material selection	4 months
Fabrication of Air Cyclone, Rig and the Purchase of some Components	4 months
source for the kaolin from the deposit to the installation site	1 months
Installation of the Rig	1 month
Test run, Analysis of both raw samples and the products and Commissioning of the Rig	2 months

Research Team

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