Chemical Composition and Particle Size Analysis of Kaolin

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Abstract. The mineral and elemental composition, crystal structure and particle size distribution of kaolin clays have been determined to ascertain its industrial significance. The mineral composition is evaluated by X- Ray Fluorescence (XRF), crystalline structure by X-Ray Diffraction (XRD) and particle size distribution using low angle laser light scattering (LALLS) technique. The results shows the presence of eight elements expressed in percentages in form of their oxides as: SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, K_2O, TiO_2 and P_2O_5. Five crystalline structures are revealed by XRD result. The particle size distribution shows that kaolin particles are mainly in the range of 25–35 μm, while few particles have size distribution varied between 0.4–0.75 μm. The report is found to be in agreement with other researchers.

Keywords: Kaolin; particle Size; composition; X- Ray Fluorescence; X-Ray Diffraction.

INTRODUCTION

The name kaolin was derived from a hill in China (Kao-ling) where it was mined for centuries [1]. Kaolin is a significant raw material with widespread application in industrial arena including water treatment, as porcelain, cement and ceramics production [2] and equally use as fillers for polymer, paint and rubber [3, 4]. Kaolin, or china clay, nevertheless relatively rare in nature, is of specific importance to the potter. It is fundamental in the manufacture of clean white porcelain. It consists of the main mineral referred to as kaolinite. The kaolin is composed of abundantly 1:1 clay mineral $Al_2Si_2O_5(OH)_4$ structure per alumina-silicate producing bulky congested particles of SiO_4 tetrahedral sheets and $AlO_2(OH)_4$ octahedral sheets [5]. The AlOHOSi hydrogen bonds is attached to each two unbroken layers since the kaolinite layer is neutral. There is a formation of an asymmetric environment of octahedral sheets which have hydroxyl groups on the interlayer surface, however the tetrahedral sheets possess oxide surfaces. These layers are less tightly bonded through Vander Waal forces together through the 'c-axis' direction. The internal surface OH groups are located virtually perpendicular to the tetrahedral sheet of the next layer preceding to creation of intensive hydrogen bonds. Hence, kaolinite has been categorised as a non-expandable mineral [6].

Some other minerals such as quartz, feldspar, anatase, and muscovite are found typically in kaolin [7]. Furthermore, crude kaolin is regularly marked yellow by iron hydroxide pigments. It is frequently essential to decolourise the clay chemically to eliminate the iron pigment and to rinse it with water to detach the other minerals, or delaminate in order to formulate kaolin for different industrial uses [8, 9, 10].

Kaolin can be used as an economical additive which can produce even dispersions to improve the properties of the product. The major characteristics of kaolin which are crucial for industrial uses includes particle size distribution, structural order, particle shape, disorder and crystallinity, specific surface area and whiteness [11]. Huge

amount of numerous properties of kaolin are regulated by the surface properties of the kaolin. Predominantly in industries, substantial loadings and viscosity are essential, these also comprise of the occurrence of absorbed surface species which modify its properties [12].

Additionally, many industrial methods use particle size as a considerable factor [13, 14]. The chemical, mechanical, and optical properties, the mixing behaviour and the bio-distribution of numerous resources and end-products are influenced by the size and shape of the particles. The results achieved by the particle size analysis involves volume distribution, standard mean diameters and distribution reports using the assumption that particles are spherical. The kaolin samples can be quantified through laser diffraction technique by bimodal distribution.

This study reports on the result on investigation of chemical constituents and particle size distribution of kaolin clay using X-Ray Fluorescence and FRITSCH Laser Particle Sizer respectively. The result is aimed to study the chemical composition and particle size distribution of kaolin obtained from an indigenous dealer Kaolin (Malaysia) Sdn. Bhd.

MATERIALS AND METHODS

Kaolin for this study was obtained from Kaolin (Malaysia) Sdn. Bhd in powdered form. By the use of hard-pressed with hydraulic press, powdered kaolin and wax were cautiously mixed and hard-pressed into pellets of 17 mm diameter in the ratio 8:2, powder to wax. 8 tonnes of MPa were operated for one minute to form the pellets. Consequently, samples were loaded in the XRF machine model (XRF Bruker S4 Pioneer) for elemental analysis. The machine was operated at maximum voltage and current 60 KV and 1 mA respectively to generate the X-rays which will energise the sample for a particular time (specifically, 10 mins) with X-ray tube of rhodium anode and scintillation detector of current 40 mA and voltage 40 mV. X-ray powder diffraction analysis was carried out using CuKα1 (λ=1.54060 Å) radiation at 0.3/min scanning rate of 2 θ range of 5–40° in a signal mode, with 0.03 phase size at room temperature on XPERT-3powder diffractometer fortified with a curved position-sensitive detector. The configurations were verified at 40 mA, 40 kV, and tests were positioned on flat bottom holder.

Particle size testing was conducted using FRITSCH Laser Particle Sizer (ANALYSETTE 22). Unique of the predefined Standard Operating Procedures (SOPs) ISO 13320 was chosen to start a measurement with the ANALYSETTE 22. The package encourages the adding of sample material [15]. The moment the quantity of sample is adequate, the measurement starts automatically. Subsequently, automatic dispersion, measurement, analysis and report generation occurs simultaneously. The system identifies, duplicates and evaluates with accuracy.

RESULTS AND DISCUSSION

XRF Analysis

The method of Elemental analyses of clays has been continuously showing the class of aluminosilicates to which the analyzed material correspond [16]. The elements determined in clays have been presented as relative percentage of the elements expressed as oxides in the whole sample as shown Table 1.

Table 1 – Mineralogical composition (XRF) of kaolin sample

Sample Chemical composition (Weight %)							
SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	TiO_2	P_2O_5
57.633	37.766	0.86	0.596	0.346	1.801	0.605	0.311

According to reports by [1] the Malaysian kaolin has high amount of silica 69.30 % and lower alumina 24.30 %. Other researchers [17] achieved silica content of 56.290 % and alumina 36.490 %; which is related to this report.

XRD Analysis

Figure 1 represents the XRD diffractograms of the kaolin.

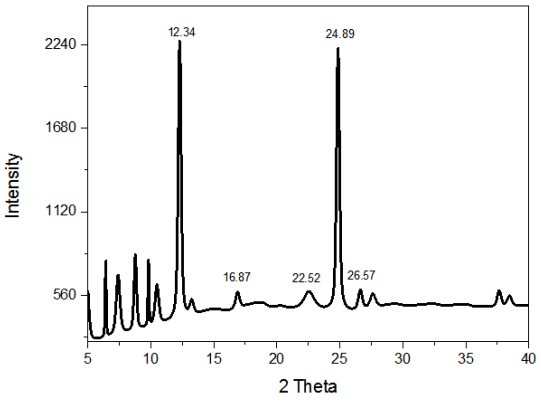

Figure 1 – XRD diffractograms of the kaolin

Five prominent peaks are detected at about 12.34°, 16.87°, 22.52°, 24.89° and 26.88°. The peak at 2 θ = 12.34° is the distinctive XRD form of kaolin. The XRD diffractograms displays the existence of five crystalline phases as summarised in Table 2 below. This report supports the XRF result obtained above.

Table 2 – Crystalline phases from XRD result

Phase	Shape	Formulae	Reference code
Silicon Dioxide	Hexagonal	SiO_2	ICSD 98-017-1734
Zeolite SSZ-16	Orthorhombic	$H_{4.14}Al_{7.2}Na_{3.06}Si_{40.8}$	ICSD 98-062-6844
Quartz low	Hexagonal	O_2Si	ICSD 98-002-0145
Carbon oxide Lt	Cubic	CO	ICSD 98-002-6962
13-Carbonylcarbidotetrairon	Monoclinic	$C_{14}Fe_4O_{13}$	ICSD 98-002-1070

Particle size distribution

Figure 2 represents the distribution of particles in relation to particle diameter vs percentage of total particle volume of kaolin samples, as evaluated by dimensions of low angle laser light scattering (LALLS) technique.

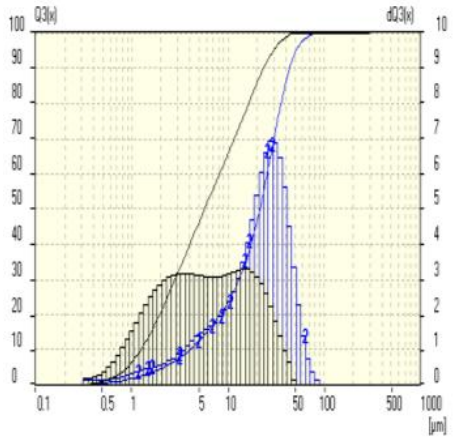

Figure 2 – Particle size distribution of kaolin

From figure 2, the particle-size dispersion of kaolin (blue line) indicates the existence of two particles assortment of sizes interchanging between 0.3 and 100 µm. The highest dispersion (~70 %) is produced by particles of 25–35 µm, with 30 µm modal size. This population complements through a lesser collection (~3 %) which involves particles of 0.4–0.75 µm, having 0.5 µm modal size. The particles has arithmetic mean diameter (De Brouckeremean diameter, $D_{4,3}$), span value (the distribution of width of size (d_{90} - d_{10})/d_{50}) and the median particle size d_{50} of 8.343, 3.653 and 5.227 respectively.

CONCLUSION

Kaolin is found to be a beneficial mineral resource not merely as a worthy basis of silica, but likewise as the origin of zeolite, quartz, and carbon oxide and carbonyl materials. This can potentially allow the manufacture of collection of valued products. Though, there is need for higher perspectives of kaolin for merchandise improvement. The study has offered altogether a valuable know-how on the compositional and particle size features of kaolin sample. Hence, additional information on the composition and particle size analysis of kaolin is appropriately imperative for the purpose of which variety of kaolin can be expended by manufacturing industries.

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