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Size Distribution Analysis of Kaolin using Laser Diffraction Technique

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Abstract. Kaolin is widely used in ceramic, paper, and pharmaceutical industries. The suitability use of kaolin in industries will depend on its physical and chemical properties. The physical and chemical composition of Kaolin is dependent on its geological origin, geographic source and processing. Processed kaolin available in the market is normally graded by the manufacturer based on its physical and chemical composition. This paper is focused on the size distribution analysis of nine types/batches of processed kaolin and one raw kaolin soil by using laser diffraction technique (based on Fraunhofer diffraction theory) in accordance to BS ISO 13320:2009. The laser diffraction technique is widely used in the powder industries in determining the particle size distribution because of its simplicity and its repeatability. All the specimens were pre-sieved with a sieve of 2mm aperture size. The effective size, uniformity coefficient and coefficient of curvature of the material were also calculated to facilitate the size distribution analysis. The findings of this paper are expected to benefit industries in which size the distribution of the kaolin will directly or indirectly contribute to its suitability use.

Introduction

Kaolinitic clay or also commonly known as kaolin had many applications; as binder for insulators, mosquito coils, pharmaceuticals, wall tiles and mattress; as an economical extender for paint; as reinforcing and pacifying fillers for rubber and plastic industries; as filler for the interstices of the cellulose fibers in paper and etc. [1] The wide applications of kaolin make it economically viable for industry to venture into specific processed kaolin to suit the specific application of each industry. The suitability applications of the kaolin in each industry are very much dependent on its physical properties such as moisture content, pH, brightness, particle size; and chemical composition. The size distribution is very important for applications such as fillers, especially if the material needs to be compacted or when the cation exchange capacity (CEC) of the particle plays an important role in chemical reaction.

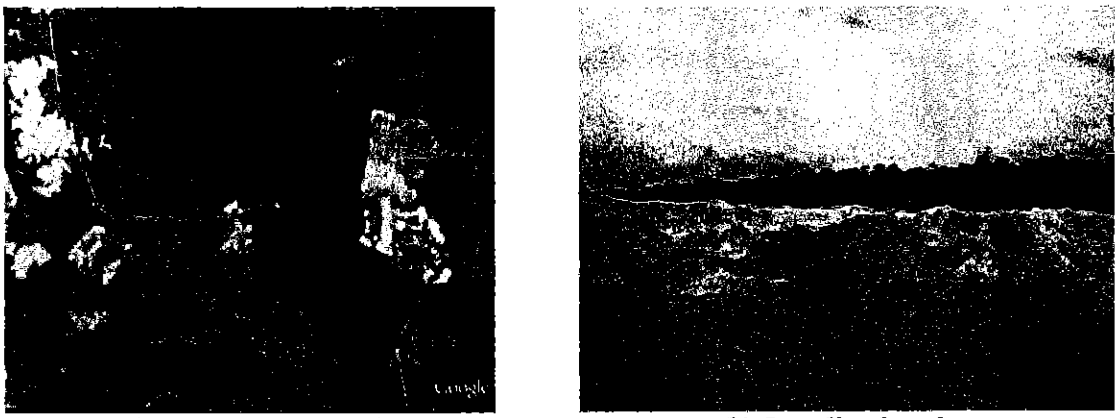
Traditionally, size distribution was determined through mechanical sieving for coarse grained material and sedimentation for fine grained material. The time consuming sedimentation test makes it an unfavorable method nowadays especially when a large number of tests need to be carried out within a short period. In addition, the sedimentation method was also found to be unsuitable with porous particles. Low density porous particles make the sediment slower than non-porous particles of similar volume. [2]

Laser diffraction technique have the advantage of detecting a wide range of sizes (15 nm to 6 μm) [3] making it favourable to the powder industry in determining particle size distribution. The principle of commercial particle size analyzer, utilizing laser diffraction technique, is based on properties of light diffraction and scattering. Two theories are used depending on the ratio of particle size over wavelength of laser light. Fraunhofer diffraction theory is an easier model to setup, in contrast to Mie theory, because the user need not provide any optical information. However, Fraunhofer approximation model will lead to an incorrect assessment of fine fraction if the material contains particle less than 2 micron. [2] Mie theory, which combine diffraction and scattering in the model, is a better choice when the particle size is smaller than the wavelength of laser light. [4]

Materials and Experimental Programme

Nine types/batches of commercial grade processed kaolin marketed by Kaolin (M) Sdn. Bhd. and one raw kaolin soil sample from Kahang, Johor (details as shown in Fig.1) were tested for its particle size distribution. The particle size analyses were carried out using CILAS Particle Size Analyzer at the Universiti Tun Hussein Onn Malaysia (UTHM). The CILAS 1180 Particle Size Analyzer (as shown in Fig. 2), utilizing laser diffraction technique with laser light wavelength, λ 635nm, is able to measure particles ranging from 0.04 to 2500 μm.

All the specimens were pre-sieved with a sieve of 2mm aperture size as a guide to prevent clogging in the particle size analyzer. The raw kaolin soil sample was crushed manually with a mortar and pestle before sieving. The particle size distribution of the materials were determined using wet dispersion mode in which distilled water was used as dispersing liquid and sodium hexametaphosphate (SHMP) was used as dispersing agent to ensure separation or dispersion of kaolin particles. However, for sample Kaolin K351020RD which is hydrophobic, methanol was used as dispersing liquid and no dispersing agent was utilized. The ultrasound was activated throughout the measuring period in order to better disperse the kaolin particles and prevent the particles from agglomerate.



(a) GPS locality of sampling location (b) Sampling location

Figure 1 Sampling location of kaolin clay at Kahang, Johor

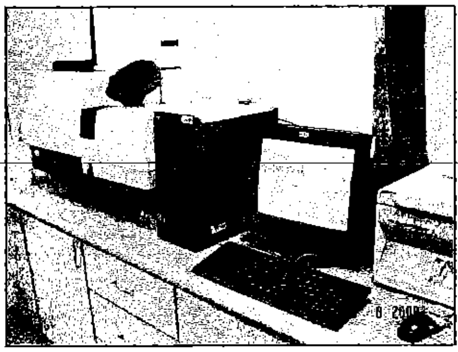


Figure 2 CILAS 1180- Particle size analyzer

Results and Discussion

The size distributions of the tested specimens were determined based on Fraunhofer diffraction theory by using the software Particle Expert V5.12. The entire tests were carried out with approximately 0.2g sample and other test procedures were in accordance to BS ISO 13320:2009 (Particle size analysis- Laser diffraction methods).

The results of the particle size distribution are listed in the Table 1 and Table 2. It is found that the kaolin soils can be categorized as well-graded in terms of size distribution. Soil that has a uniformity coefficient greater than 4 and coefficient of curvature in between 1 and 3 indicating the soil is well-graded [5]. Based on the size distribution, the majority of the kaolin particles are silt sized. The particle size of the material is different from the crystalline size because a particle may be made up of several different crystals. [6] Hence, the size distribution of the particle cannot be utilized to determine the purity of the kaolinite clay. In addition, it is also reported that kaolinite may occur as crystals in the size of a micron up to several hundred microns. [7]

Fig. 3 and Fig. 4 showed the particle size distribution and the distribution histogram of the processed kaolin and kaolin clay from Kahang, Johor, respectively. It is observed that the distribution of most particles are located in the central region of the particle size distribution curve which made it almost like a bell shaped graph. The size distribution test was repeated three times for raw kaolin clay Kahang, Johor as shown in Fig. 4. The min, max, mean and standard deviation (refer to Table 3) were calculated to determine the validity of the sampling size. The results also showed that that the sampling size is suitable in representing the size distribution of mass sample with low variations in between three samples.

Table 1: Particle size distribution of kaolin

No.	Type of kaolin	Effective size, D_{10} (μm)	D_{30} (μm)	D_{60} (μm)	Uniformity Coefficient, UC[1)]	Coefficient of Curvature, Cc[2)]	Comments
1	Kaolin FM-C	1.31	3.57	7.37	5.626	1.320	Well-graded
2	Kaolin FM (old batch)	1.21	3.36	7.11	5.876	1.312	Well-graded
3	Kaolin S300	4.53	13.48	28.24	6.234	1.420	Well-graded
4	Kaolin S300 (new batch)	4.44	12.22	22.83	5.142	1.473	Well-graded
5	Kaolin KM40	1.30	3.52	7.07	5.438	1.348	Well-graded
6	Kaolin KM55	1.25	3.40	7.09	5.672	1.304	Well-graded
7	Kaolin L2B20 (Pink colour)	1.59	5.70	13.31	8.371	1.535	Well-graded
8	Kaolin DL2 (Pink colour)	1.58	5.21	10.76	6.810	1.597	Well-graded
9	Kaolin K351020RD (Hydrophobic)	1.30	3.72	7.25	5.577	1.468	Well-graded
10	Kaolin clay (from Kahang, Johor)	1.13	3.12	5.85	5.177	1.473	Well-graded

1) $UC = \frac{D_{60}}{D_{30}}$; 2) $Cc = \frac{D^2_{30}}{D_{10}D_{60}}$

Table 2: Percentage distribution of particles

No.	Type of kaolin	Percentage distribution (%)		
		Clay size <2 μm	Silt size 2 < x < 63 μm	Sand size 63 < x < 2000 μm
1	Kaolin FM-C	16.89	83.11	0
2	Kaolin FM (old batch)	18.42	81.58	0
3	Kaolin S300	4.37	91.9	3.73
4	Kaolin S300 (new batch)	4.92	94.94	0.14
5	Kaolin KM40	17.21	82.79	0
6	Kaolin KM55	17.92	82.08	0
7	Kaolin L2B20 (Pink colour)	12.50	87.41	0.09
8	Kaolin DL2 (Pink colour)	12.72	87.28	0
9	Kaolin K351020RD (Hydrophobic)	16.16	83.84	0
10	Kaolin clay (from Kahang, Johor)	20	80	0

Table 3: Min, max mean and standard deviation of size distribution

Details	Test ID	Diameter at 10% (micron)	Diameter at 50% (micron)	Diameter at 90% (micron)
Min		1.104	5.744	18.759
Max		1.138	5.964	20.047
Mean		1.125	5.853	19.205
Standard deviation		0.019	0.110	0.730
Size distribution	371	1.134	5.849	18.759
Size distribution	372	1.138	5.964	20.047
Size distribution	373	1.104	5.744	18.807

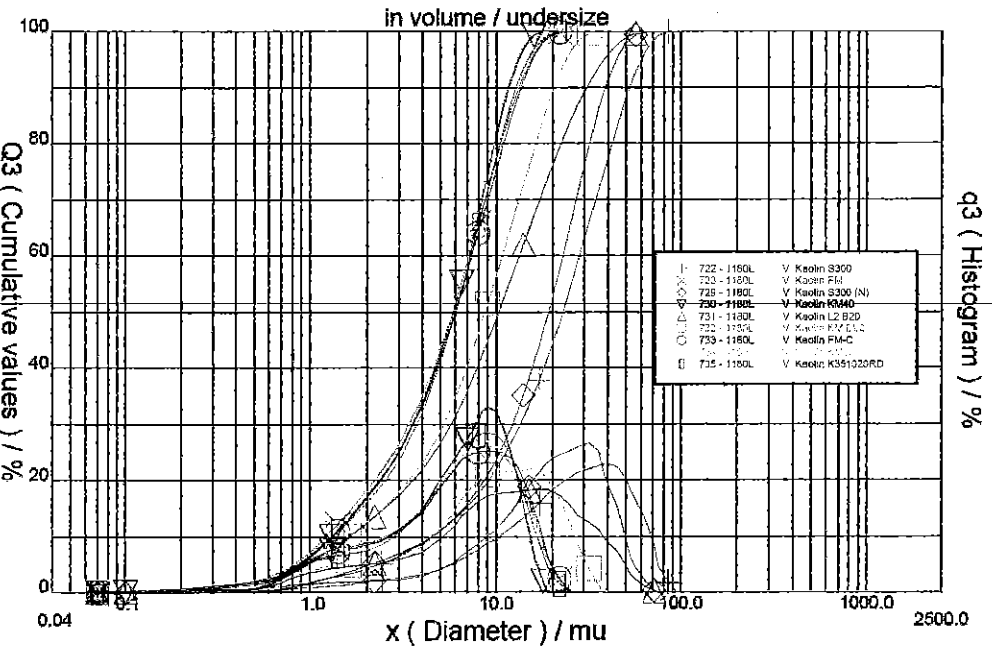


Figure 3 Particle size distribution & distribution histogram of processed kaolin

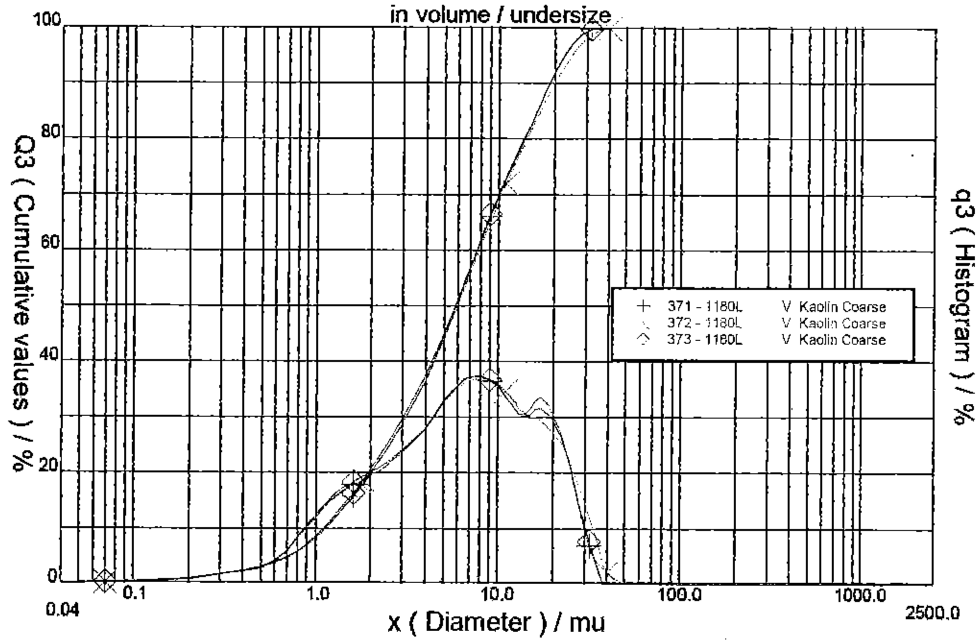


Figure 4 Particle size distribution & distribution histogram of kaolin clay Kahang, Johor

Conclusions

It can be concluded that the processed kaolin are well graded and mainly silt sized. The small differences of particle size distribution between the raw kaolin clay and the processed kaolin indicated that the particle size was not affected by the wet production method adopted by the local kaolin manufacturer. However, if high accuracy of size distribution is required, Mie theory is recommended as the kaolin contains a significant amount of small particles which are less than 2 micron.

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