EFFECT OF DIFFERENT POLYHYDROXYLIC DISPERSANTS ON DISPERSION STABILITY OF KAOLIN PARTICLES+

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Abstract

Controlling of ceramic properties is considered as one of the important steps that has to be taken. This has been carried out using different hydroxyl compounds as dispersants for two types of Sudanian kaolin, Merkhiat and J. Umm Ali. They were glycerin, glycerin jelly, poly(ethylene glycol) and Arabic gum. The dispersion stability was examined using sedimentation test under gravity in aqueous medium. It was found that good dispersions were obtained. Most of the kaolin particles settled as good deflocculated suspensions, whereas aggregation was much easier with kaolin suspension having no dispersant. This was reflected on the final packing density of the sediments. It was also found that the type of dispersant and its concentration have an influence on the final packing density. Arabic gum and Merkhiat kaolin were the best.

المستخلص

تعد عملية السيطرة على خصائص السيراميك من الخطوات المهمة، لقد تـم ذلـك باسـتخدام مـواد بـولي هيدروكسيلية مختلفة كمواد مشتتة لنوعين من الكاؤولين السوداني (مرخيات و جبل أم علي)، وهي الكليـسيرين، الكليسيرين الهلامي، بولي(أثيلين كلايكول) والصمغ العربي . اختبرت استقرائية العوالق المشتتة باستخدام عمليـة الترسيب تحت الجاذبية الأرضية، فتم الحصول على استقرائية جيدة لجسيمات الكاؤولين بوجود المواد المشتتة أعلاه، بينما لم تكن الحالة كذلك بغياب هذه المشتتات. لقد انعكس هذا على كثافة الرص النهائية لحجم الكاؤولين المترسب، والذي تأثر بنوع وتركيز المادة المشتتة. كانت أفضل النتائج مع استخدام الصمغ العربي وكاؤولين مرخيات.

Introduction

Addition of dispersant is of the prime need in ceramic processing. Dispersants are most preferably organic compounds, some are of natural origin such as animal or vegetable fats and wax [1], and some are synthetic products, such as low molecular weight polymer or controlled structure copolymers [2,3]. They are offered mostly as free-flowing and nonagglomeration powders.

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For a good and high sediment density, the particles must be completely dispersed in solvent and show no agglomeration. Thus the function of dispersant is to suspend particles in a liquid media so as to minimize the strength of inter-particle interactions. This can be achieved by providing a surface charge and/or thick layer on the particle to prevent agglomeration. A good dispersant will offer many benefits. It will give efficient deagglomeration of the powder and resist flocculation of the particles, by promoting their dispersion in dispersion media (aqueous or organic) during slurry formation [4], which is of considerable importance to the overall properties of ceramic and surface coating [5].

The degree of dispersion of a particle suspension may be defined as the extent to which the individual powder particles become separated from one another in the liquid medium [6]. The common methods, of course include the observation of the particle settling rate and final packing density; slow settling and/or good packing density are taken to imply good dispersion stability.

Clay has always been the chief ingredient in ceramic industry, although many refractories and electronic bodies are made with little or no clay, nevertheless, kaolin and various types of clays are still our important ceramic raw materials [7]. The characteristic properties of clays are imparted by their main functional components, the clay minerals, which are aluminosilcates containing hydroxyl groups. The common features of clay minerals are their layered structure and their occurrences as very fine particles. The physical and technological properties of clays depend not only on the composition and structure of the respective clay minerals, but also on the particle size and shape.

In the present work the dispersion behaviour of two different types of kaolin, namely Merkhiat and J. Umm Ali was observed in the presence of various polyhydroxylic water-soluble dispersants.

Experimental

Adsorbents

Clay deposits of different types and quality occur in many areas in Sudan [8]. For example, kaolinitic clay deposits are known to occur in several localities including those kaolinite deposits located in the basement complex in J. Umm Ali north of Shendi and Merkhiat Hills NW of Omdurman.

J. Umm Ali and Merkhiat Kaolinitic Clays

J. Umm Ali lies on the eastern bank of the river Nile. The main mineral composition of kaolinitic sediments is as follows; kaolinite: 56-72%, quartz: 20-34% and Fe-oxide: 2-4%.

Merkhiat deposits are located in North West of Omdurman. It They consist of 40-50% kaolinite, 40-55 quartz, and up 2% goethite. Their chemical compositions shows the presence of some metal oxide in addition to the main two components of silica and alumina, Table (1).

The sampler were sieved using Podemorse sieving machine No. 15104/ England. For both types of kaolin, the fraction passed through sieve of 90 μm and were retained on 32 μm sieve which was taken to be used in this work

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Table (1): Chemical analysis of J. Umm Ali and Merkhiat kaolinites.*

Type / Oxide%	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	Na_2O	K_2O	L.O.I.
Umm Ali	58.36	26.54	1.99	0.42	0.12	2.28	0.13	0.35	9.84
Merkhiat	61.85	20.11	1.21	0.23	0.54	1.59	0.21	2.16	10.1

* Carried out in the Department of Geological and Mineral Resources (Khartoum).

Dispersing agents

Different types of polyhydroxylic compounds were used as dispersing agents for kaolin in water as a dispersing medium.

Arabic Gum is the oldest and best known of all natural gum. It was successfully used in different applications, for example as a binder in pigments and cosmetics, as a adhesive in painting, and as an agent in different mummification processes [9]. It was obtained in form of powder from GAPC of Sudan.

Also the ability of some polyhydric alcohols, glycerin, glycerin jelly and poly(ethylene glycol), was tested as a dispersant of kaolin particles, and they are obtained commercially.

Dispersion Process

Dispersions were prepared by mixing four grams of desired kaolin with a known concentration of the dispersing agent in a stoppered 10ml-graduated cylinder. They were agitated manually and ultrasonically for at least 1 hour, and then they were allowed to stand at room temperature until settling was complete. The height of the top surface of the solid bed was monitored as a function of time.

The packing density of the final particle bed was measured and is expressed as a fraction of the theoretical density of a fully dense ceramic. Perfect packing of spheres would yield a density of 74%; random close packing of spheres gives 69% density. Agglomerated particles typically settle rapidly to packing densities of the order of 20%. Dispersants giving packing densities in the range from 30% to 60% are currently regarded as good.

Results And Discussion

Since physical measurements on any dispersion can lead to better understanding of the state of dispersion, sedimentation test under gravity was made to evaluate the ability of that Arabic gum and the polyhydric alcohol as dispersant for both types of kaolin used in this work. Water was chosen as dispersion medium (solvent) for these settling experiments because it is the most common solvent, which has been used in ceramics processing, due to many reasons including its availability and cheapness, and of course being a non-toxic solvent. All of the conditions were kept constant, i.e. powder mass and time of settling.

The sedimentation rates were taken to be the speed at which the interface between the supernatant liquid and the consolidation sediment moved down. This allows comparison in terms of settling rate and of the final sediment volumes directly. Although all the dispersants contributed to the dispersion of kaolin in water, some of them increased the stability of dispersions very much more than others.

By examining the top surface of both types of kaolin particles settled in different concentrations of glycerin as a testing dispersant, Fig (1), we can observe that the top surface of the compacts tends to flatten especially in the of Merkhiat kaolin, Fig. (1 a). In addition, the supernatant solution of the better dispersions remained opaque for several days although the sedimentation took place within a day or less. As sedimentation proceeded the uppermost part of the supernatant liquid became clearer, while the lower part remained opaque. The boundary between the cloudy and opaque portions of the supernatant liquid gradually moved downward, leaving very fine particles floating in the suspensions. In some cases, these fine particles stayed in the supernatant liquid for two months (the maximum time given for these types of experiments). This type of settlement is called fast settlement in which the final particle packing density is not necessarily high [2].

The settling rate of the sediments is considered to be sensitive to the type of dispersant and its concentration, as can be seen in Fig. (2) using glycerin jelly as dispersant. It can be seen very clearly that the final volume of the sediment bed was lower than that of glycerin for both types of kaolin. Apart from the floc and the opaque supernatant, the settling was completed in a few days, with much lower sediment volume in case of Merkhiat kaolin particles and it is of course affected by the concentration of glycerin jelly.

Examining Fig. (3), concerning the settlement of both types of kaolin particles in different concentrations of poly(ethylene glycol) as dispersant, one can easily conclude that the polymer structure has an effect on the settling of the kaolin particles. It is clear that the particles tend to settle more slowly in different concentrations of poly(ethylene glycol) solution; although the final packing is different, this of course, is estimated by measuring the final sediment volume, which is again much lower in Merkhiat kaolin in spite of the fast settling of their particles, Fig. (3 a), than that of the sediment volume obtained with Umm Ali particles settled from aqueous solution of the poly(ethylene glycol) dispersant, Fig. (3 b).

From the results mentioned above, we can say that increasing the number of hydroxyl groups in dispersant molecule has improved the dispersion stability in terms of sedimentation rate, although the active group was the same, i.e. hydroxyl groups. Doroszkowski and Lambourn [10] made similar observation. They found that increasing the length of the acetate side chain by just three (-CH_2-) links causes very large increase in stability. This implies that surface concentration is very important in influencing dispersion stability [11].

The breakthrough came from using Arabic gum as a dispersant for both types of kaolin particles. The results obtained are shown in Fig. (4 a) for Merkhiat and in Fig. (4 b) for Umm Ali Kaolin. The main observation can be made from Fig. (4) is that the settlement needs more than seven days and may be more with Merkhiat particles depending on the Arabic gum concentration. The final sediment volumes of the kaolin beds, were significantly lower than those for any previous additives used so far, implying very much better packing of the particles. This type of sedimentation behaviour is typical; of deflocculated dispersions [3,12]. One can easily distinguish between dispersions with the Arabic gum; more time was needed to achieve final settlement with Merkhiat kaolin than in the case of Umm Ali kaolin particles, Fig. (4 b).

The above results reveal that using no dispersants with both types of kaolin, in the settling experiments, some coagulation to the inside wall of cylinder gives a good indication of flocculation. However additions of the dispersants enhance the dispersibility of kaolin particles, and enhance the degree of deflocculation. This was further explored by measuring the packing density of sediments after gravity settlement. The results obtained are illustrated in terms of %packing density, in Table (2) for Merkhiat kaolin and in Table (3) for Umm Ali kaolin.

It can be seen very clearly that the type of dispersant added has a good influence on the measured packing density as it has on their settlement, and the packing densities obtained with Merkhiat kaolin powder are much higher than those obtained from Umm Ali kaolin powder, although the effective concentration ranges between (3-4)wt% for all type of dispersing agents used, Tables (2) and (3). It is also obvious that Arabic gum produces the much better packing densities for both types of kaolin, and with Merkhiat kaolin being the best. This can be attributed to better physical and chemical properties, since Arabic gum molecules behave in solution as a complex macromolecules [9,11].

Table (2): Packing densities of Merkhiat kaolin powder dispersed in water solution of various dispersing agents.

Concentration of Dispersant (wt%)	% Packing Density			
	Glycerin	Glycerin jelly	Poly(ethylene glycol)	Arabic gum
0.5	62.27	62.89	61.62	64.31

1	61.53	62.95	61.11	66.36
2	62.01	63.17	61.28	66.49
3	62.75	63.58	61.82	66.88
4	61.84	65.07	62.57	66.28
5	61.84	64.66	62.57	65.89

Table (3): Packing densities of Umm Ali kaolin powder dispersed in water solution of various dispersing agents.

Concentration of Dispersant (wt%)	**% Packing Density**			
	Glycerin	**Glycerin jelly**	**Poly(ethylene glycol)**	**Arabic gum**
0.5	59.62	56.41	57.26	59.41
1	59.51	56.32	57.45	59.69
2	59.25	56.17	57.94	59.91
3	58.69	56.09	58.24	60.26
4	56.65	55.81	58.46	61.14
5	58.44	55.96	57.49	61.07

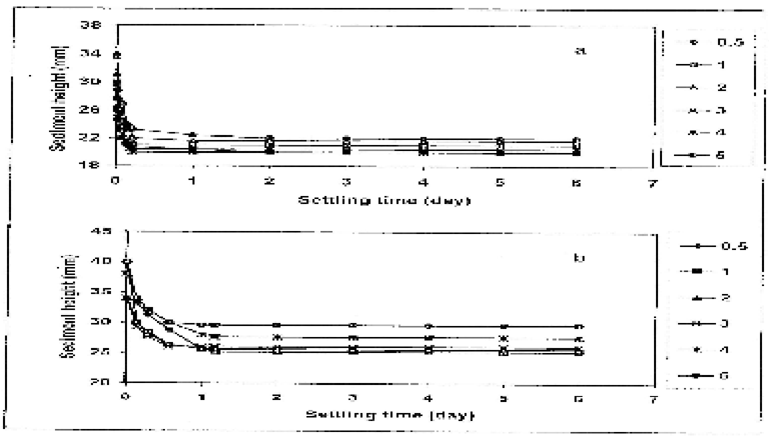

Figure (1). Sediment height of kaolin powders settled from different wt% of glycerin; (a) Merkhiat kaolin, (b) Umm Ali kaolin.

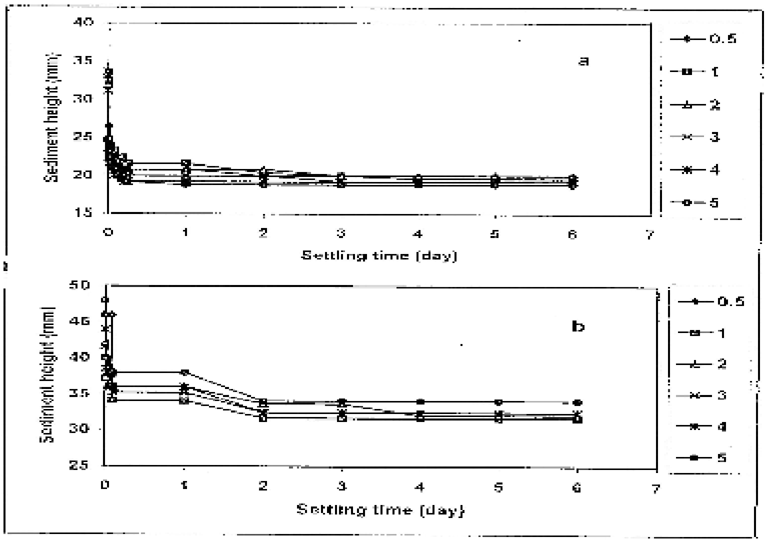

Figure (2): Sediment height of kaolin powders settled from different wt% of glycerin jelly; (a) Merkhiat kaolin, (b) Umm Ali kaolin.

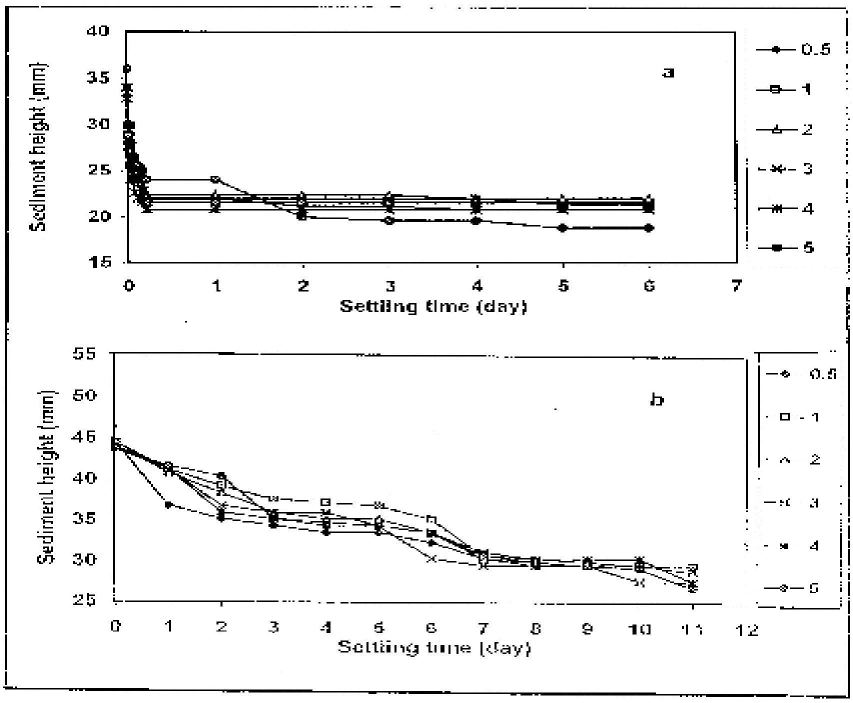

Figure (3): Sediment height of kaolin powders settled from different wt% of poly(ethylene glycol); (a) Merkhiat kaolin, (b) Umm Ali kaolin.

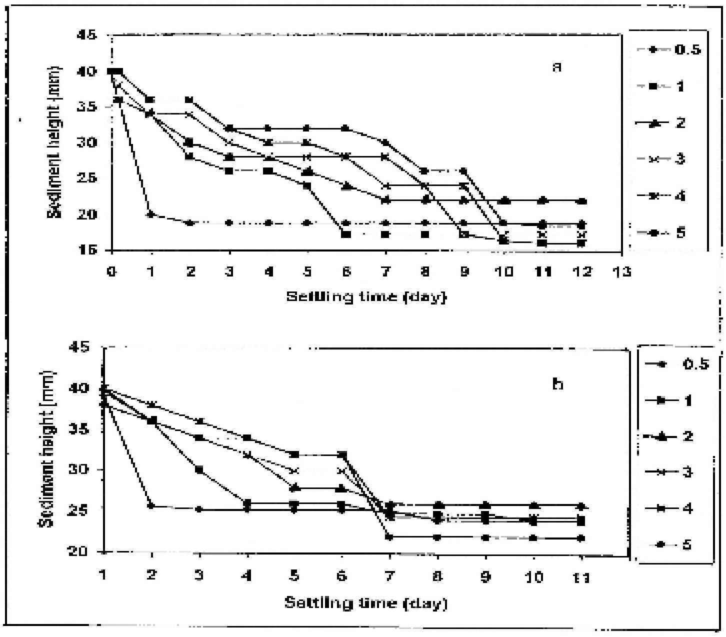

Figure (4): Sediment height of kaolin powders settled from different wt% of Arabic gum; (a) Merkhiat kaolin, (b) Umm Ali kaolin.

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