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Stability and rheology of aqueous suspensions

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Abstract

Stability of aqueous suspensions of metal oxides and minerals based on aluminosilicates with various particle sizes distribution was measured by the rate of sedimentation, sedimentation volume and zeta potential for various concentrations of solid phase and different pH. Two kinds of TiO_2 and one Bentonite were chosen as solid dispersed particles in distilled water. Rheological properties of such materials were monitored. pH was modified by adding of NaOH and HCl aqueous solutions and was measured as complementary parameters. Rheology was measured by rotational viscometer equipped by sensor of coaxial cylinders. Dynamic light scattering method was used for evidence of zeta potential. Isoelectric point was detected from course of function of zeta potential on pH. Range of pH when zeta potential is out of range (-30 30 mV) was detected. Outside this region the suspension stability should be higher than inside, which was confirmed by sedimentation and viscometric experiments. With increasing pH both zeta potential and sedimentation velocity decreases.

Keywords: Suspension stability, viscosity, zeta potential, bentonite, TiO_2

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Nomenclature

K	coefficient of consistency ($Pa.s^n$)
n	flow index (1)
σ_R	shear stress (Pa)
γ	shear rate (1/s)
ζ	zeta potential (mV)

1. Introduction

Disperse systems plays important role in human everyday life. Such systems can be classified with respect on particle size onto severe classes: colloidal solutions, nano dispersions, micro dispersions and coarse dispersions. There are various applications of such materials i.e. in health care and food industry, pigments and so on. Rheology was found as a suitable method not only for determining of transport characteristics but also as the quality parameter for such micro dispersions [1-10].

Two kinds of pigments based on titanium white and one clay type material was tested. Titanium white is titanium oxide in pigment form which is one of most nowadays used white pigments. Its application range is wide from pigments to paper industry, health care medical applications, as catalyst or photo catalyst and so on. Clays are applicable not only in ceramics industry but also in the field of new materials composites or carriers of active components. Knowledge of behavior of such materials in dry or dispersed form plays important role in process design.

Both, properties at solid liquid interface (zeta potential) and bulk flow properties were at the point of interest of this paper. Zeta potential is one of the important properties for classification of stability of dispersed systems. When dispersion is unstable, i.e. rapid sedimentations occurs, the flow characteristic as flow or viscosity function cannot be determined without drastic misinterpretation [11-13].

Aim of this paper was determine conditions when prepared dispersions are stable enough and determine flow properties represented by flow curves.

2. Experimental

Dry powder of two samples of TiO_2 in Anatas crystalline form grade PK 60 and PK 180 and one dry powder sample of Bentonite clay grade B70 was used as source materials. Three suspensions of different concentrations were prepared from each powder sample. Range of concentrations varies from 5 -20 vol. % for TiO_2 and from 10-20vol % form Bentonite clay. Three or four samples of different pH were prepared for each concentration of suspensions, i.e. about 30 samples was tested in total. Distilled water was used as a solvent and 1M solution of NaOH or HCl p.a. grade was used as pH modifiers.

2.1. Methods

Sedimentation of prepared suspensions was observed for five days in glass tubes of 100ml volume. There was no manipulation with tubes during experiment and evaporation of water was prevented by employing rubber plug.

Zeta potential was measured using Zetasizer Nano ZS. Apparatus register electro mobility of particles involved in to the electric field by dynamic light scattering method (DLS). Application of Smoluchowski theory allows us to convert experimental data to information about zeta potential. Ambient condition during electro kinetic experiments was as follows: temperature 23°C, refractive index of solvent 2.5 and absorbance 3. Zeta potential by definition does not depend on concentration of solid particles dispersed in the solvent. Dilute dispersions of all of three studied materials were tested under different pH conditions. Auto titration tool was employed when experiments with wide range of pH was carried out.

Viscometric experiments were carried out on rotational rheometer Haake RS 100. Viscometric sensor of coaxial cylinders consisting of cylindrical cup and cylindrical rotor of diameter 40mm. Regime controlled stress has been used, when torque is adjustable quantity and angular speed of rotor is registered quantity. Viscometric experiments were carried out at 25°C ambient temperature. Resulting flow curves are discussed below in section results.

3. Results and Discussion

3.1. Electro kinetic experiments

Classification of dispersion stability is possible to evaluate from Fig. 1. Generally, when zeta potential is greater than 30mV or smaller than -30mV the dispersion behaves as stable. Such region was identified for all of tested samples. With increased pH the significant decrease of zeta potential was observed. Tested dispersions behave as non-stable when pH is very low. Contrary at high pH (above value 8) all tested samples seems to be stable. Only the sample of PK 60 seems to be stable also at very low pH values (1-2.5). Values of zeta potential for Bentonite are almost constant at acid range of pH. When pH exceeds value 8 perceptible difference was monitored.

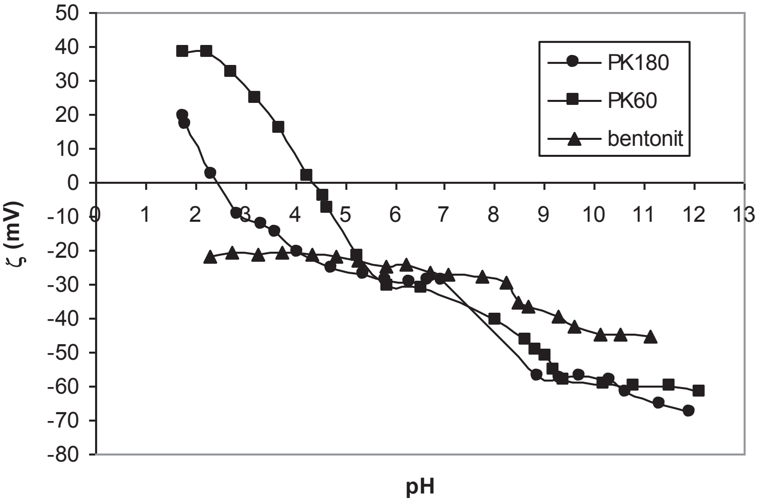

Fig. 1. Zeta potential as a function of pH

Interesting information which can be finding out from Fig. 1 is isoelectric point (IEP). It is value of pH where zeta potential is equal to zero. IEP was determined only for pigment samples (PK60, pH=4.33 and PK180, pH=2,45). IEP for Bentonite sample was not detected.

Instability of tested samples at low pH observed in electro kinetic experiments was confirmed by sedimentation experiments where samples at lower pH sediments much faster than samples at higher pH.

3.2. Flow curves

Flow curves of tested samples are depicted in Fig. 2 Power law model was employed for experimental data interpretation *(1)*.

$$\sigma_R = K\,\gamma^n \qquad (1)$$

where σ_R is shear stress, γ is shear rate, K is coefficient of consistency and n id flow index.

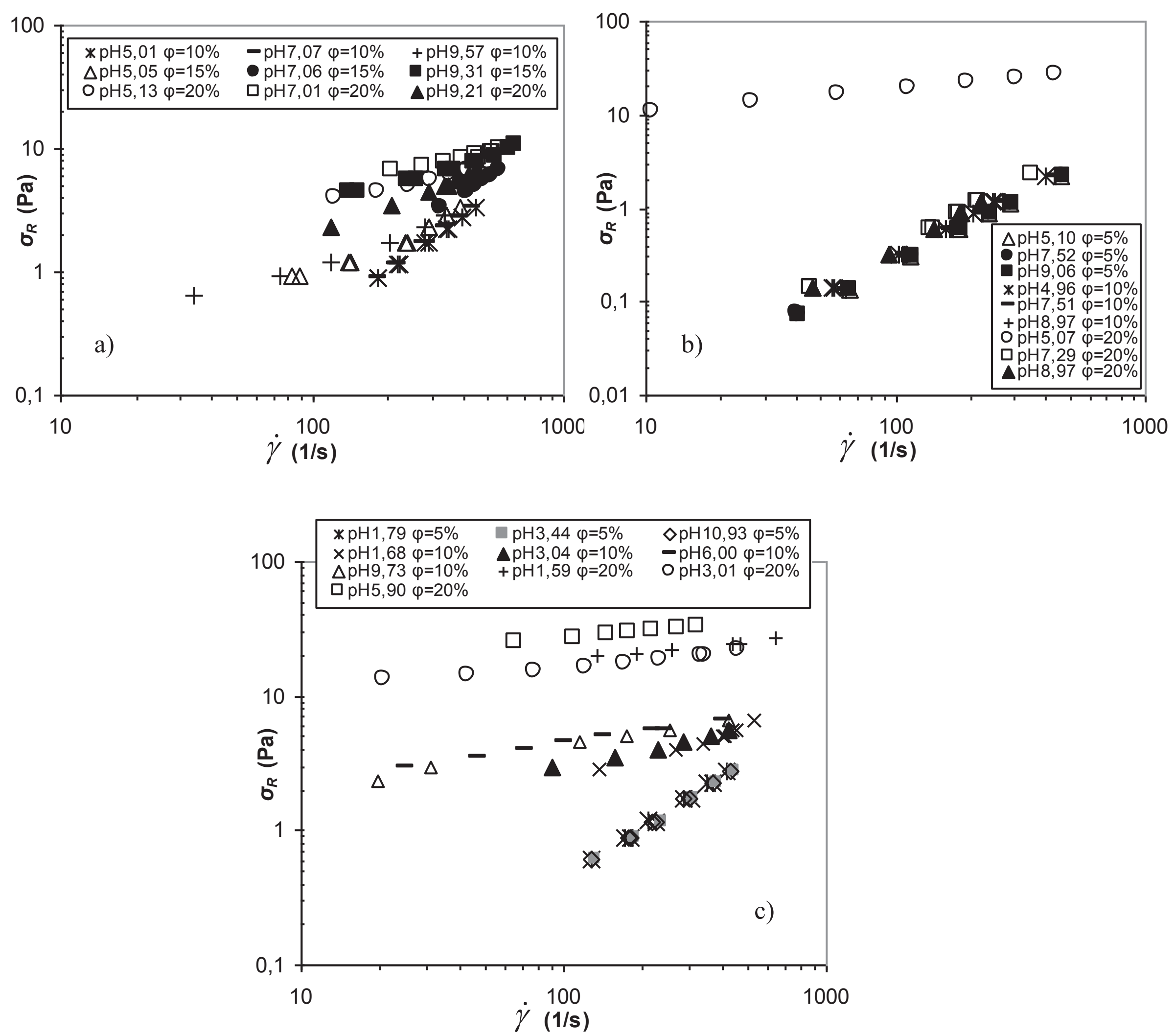

Fig. 2. Flow curves of tested samples a) Bentonite sample b) PK180 sample c) PK 60 sample, numbers in legend represent values of pH and φ denotes volumetric concentrations

Consistency of most concentrated suspensions are highest, consistency of low concentrated suspension was lowest. Stable samples at high pH and sample PK60 at very low pH have at the same concentration similar consistency. Sample of PK180 with concentration of 20 vol % is strongly affected by sedimentation and measured flow curve is out of trends of other relatively stable samples. Other tested dispersions follow the rules described above.

4. Conclusion

Aqueous suspensions of three different powders were tested on stability at different pH conditions. Measured samples of different concentration were instable at low pH conditions excluded sample PK60 which was found partially stable at extremely low pH. Dispersion of samples PK180 and PK60 are most stable when pH exceeds value 8 when zeta potential was determined as almost constant. Dispersions of clay is most stable at pH 10 and higher when zeta potential is also find as constant. Isoelectric point was determined only for pigment samples. Bentonite sample has zeta potential at negative values in all the range o tested pH.

Flow curves display that most concentrated suspensions are most consistent and consistency increase with decreasing pH. From electro kinetic experiments we determine that at low pH the stability is poor and thus flow curves are negatively affected by rapid sedimentation of dispersed solid phase.

Acknowledgements

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