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Application of surfactants to reduction of fractures in ceramic materials during drying

Introduction

Clay-like materials are widely used in ceramics industries for production of buildings elements and sanitary ware. Before forming into specific products the raw material is mixed with an appropriate amount of water to get a plastic mass. After forming the products are subjected to drying and next firing. Unfortunately, the capillary-porous structure of clay-like materials is prone to shrinkage and cracking during drying [*Pampuch, 1988*]. This weakens the mechanical strength of the products and significantly reduces the possibility of their usage.

The reasons for material cracking are the stresses inducted in the material during intensive drying, when the moisture distribution become nonlinear. To improve transport of moisture inside the drying clay and avoid material cracking the authors propose wetting the raw clay-like materials with water containing surface active agents (surfactants). Surfactants are compounds composed of both lipophilic and hydrophilic fragments. Surfactants tend to be scarcely soluble in water as free molecules or ions, but they are able to form stable colloidal aggregates called micelles, when the concentration is above the *Critical Micelle Concentration* (CMC). For the improvement of moisture transport the surfactants concentration should be below CMC [*Nystrom et al., 1994*].

The main goal of this work was to investigate the effect of the stearate sodium sulfate surfactant on the reduction of the drying induced stresses in clay-like materials during drying [*Paulenowá et al., 1998*]. The experiments were carried out on cylindrical samples molded of kaolin-clay wetted with water solution of different surfactant concentration. The samples after leveling the moisture distribution were subjected to convective drying in hot air at temperature 90°C in a dryer chamber. The acoustic emission (AE) method was used to monitor the stress development in drying samples. Besides the samples were observed and photographed to visualize their shrinkage during drying.

Materials and methods

Experimental

The drying tests were carried on in the laboratory chamber dryer *Zalmed SML42/250/M* equipped in the acoustic emission system. The experimental equipment used for the tests is presented in Fig. 1.

Drying parameters such as the temperature and the relative humidity of air were measured every half minute during drying with the Pt 100 temperature probe and humidity sensor *DO 9861T Delta OHM* (Italy). The AE sensor was attached to the bottom surface of the sample, and the registered AE signals were transmitted into electric ones and strengthened by the amplifier.

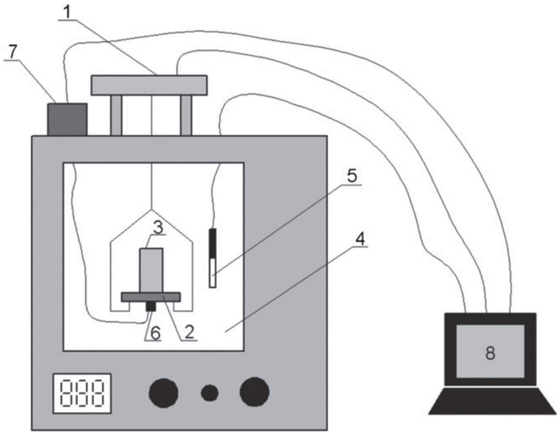

Fig. 1. Experimental set-up: *1* – balance, *2* – scale pan, *3* – sample, *4* – dryer chamber, *5* – temperature sensor, *6* – AE sensor, *7* – amplifier of AE signal, *8* – computer

Materials

The tested samples in the form of cylinders were made of kaolin-clay delivered by the *Surmin Kaolin Company SA* (Poland). The preparation of clay samples consisted of the following steps. In the first step the dry kaolin has been grounded to powder. The powder of amount 200 g was mixed with 100 ml of pure water or water solution containing specific amount of surfactant. These ingredients were mixed by hand to get a thick paste. Next, the wet kaolin having a state of thick paste was stored in an airtight container at room temperature for 24 h to equalize the moisture distribution in the whole material. The thick paste was of initial moisture content approximately 35% (dry basis). The obtained in this way soft clay mass was used to mold cylindrical samples ($D = 44$ mm, $H = 50$ mm).

Acoustic emission

The AE method is becoming a very popular measurement and diagnostic technique in materials engineering [*Malecki and Ranachowski, 1994*]. AE energy generated in drying materials because of cracks is transported throughout the material in the form of acoustic waves. The acoustic signals are registered by the AE sensor installed at the material surface and the AE descriptors like AE energy per a time period (e.g. 30 s), total AE energy, total number of AE signals, etc. were measured. The advantage of the AE method is that it enables monitoring on line the development of crack formations, revealing in this way the history of stress generation.

Results and discussion

All drying experiments were performed convective drying in the dryer chamber at constant air temperature of 90°C for which the air relative humidity amounts c.a. 2÷3%. Such a temperature ensures a high drying rate. Each test was repeated at least three times.

Kaolin-clay without surfactant

Figure 2 presents the typical drying curve of kaolin-clay during convective drying and the descriptors of total AE energy and total number of AE signals for kaolin-clay wetted with pure water.

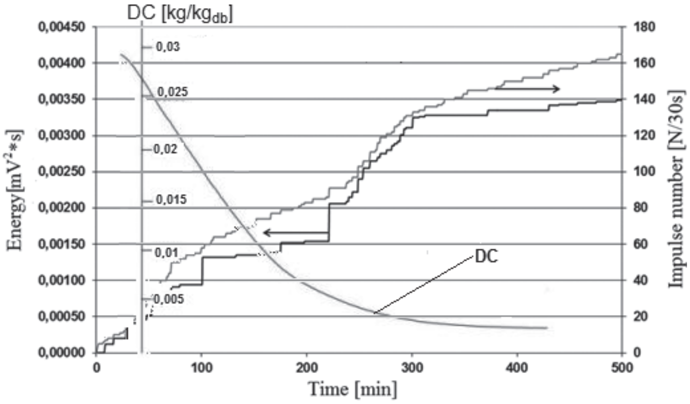

Fig. 2. Drying curve, total AE energy, and total number of AE impulses in clay samples saturated with pure water

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The vertical lines on the descriptor of AE energy inform about cracks formed in the material at the given moments. The AE descriptors presented in Fig. 2 show rather an intensive emission of both the AE energy and the number of AE signals.

Kaolin-clay with surfactants

Fig. 3 presents the results of drying tests for kaolin-clay samples wetted with surfactant solution of the concentration 0,1%, which is above CMC.

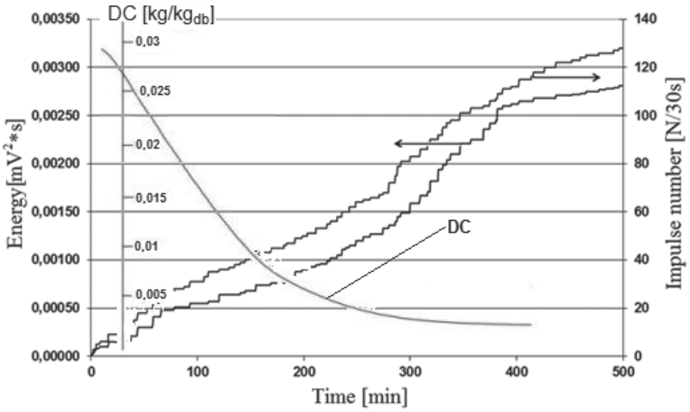

Fig. 3. Drying curve, total AE energy and total number of AE impulses in kaolin-clay saturated with water solution containing 0.1% stearate sodium sulfate

One states that in this case the drying time was similar as that for kaolin-clay wetted with pure water, however, the AE descriptors show smaller values of both the AE energy and the number of AE signals.

When the surfactant concentration is equal or below CMC, the surfactant is always dissolved as monomers. Water solution with surfactant concentration equal or slightly below CMC is favorable for better moisture transport in pores of the kaolin-clay materials. Fig. 4 presents the results of drying tests for kaolin-clay samples wetted with surfactant solution of the concentration 0,01%, which is slightly below CMC

Comparing the AE descriptors in Fig. 2–4 we see that the amount of the AE energy and the total number AE signals are the smallest for the kaolin-clay processed with water solution containing the concentration of stearate sodium sulfate surfactant slightly below CMC. It was stated that also the drying time was remarkable shorter in this case than in the previous ones. So, the addition of a surfactant to water solution in an amount close to CMC improve significantly the drying effects, and in particular decreases the destruction phenomena, what results in a better quality of dried products.

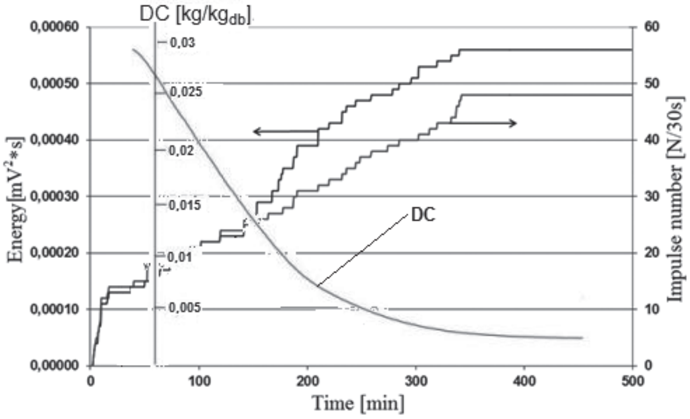

Fig. 4. Drying curve, total AE energy and total number of AE impulses in kaolin-clay saturated with water solution containing 0.01% stearate sodium sulfate

Fig. 5 presents for comparison the descriptors of total AE energy for kaolin-clay samples wetted with pure water and the water solutions of surfactant concentration 0,1% and 0.01%, respectively. We see a significant difference in the amount of AE emitted in these three cases.

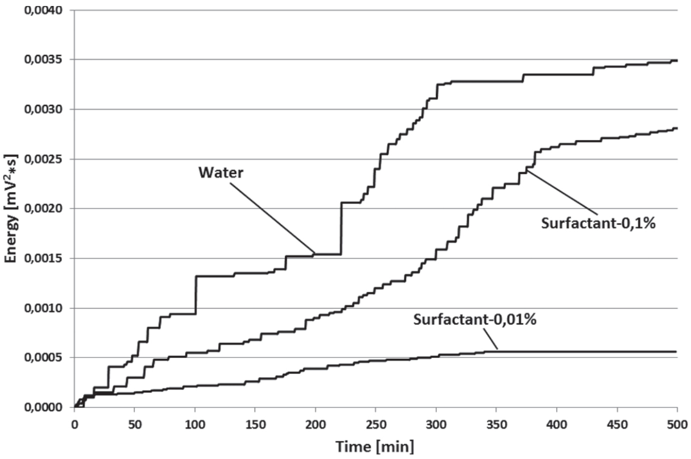

Fig. 5. Descriptors of total AE energy for kaolin-clay samples saturated with pure water and the water solutions of 0,1% and 0.01% surfactant concentration

Fig. 6 presents the shrinkage curves for kaolin-clay samples wetted with pure water and with water solution of 0.01% surfactant concentration. It is seen that the shrinkage of sample wetted with pure water is greater than that wetted with water-surfactant solution, and that the shrinkage of the latter sample ends c.a. 40 min earlier that that wetted with pure water.

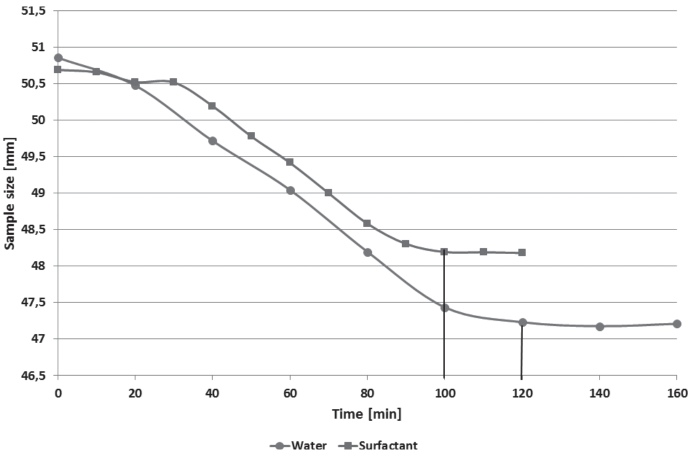

Fig. 6. Shrinkage curves for samples wetted with pure water and with water solution of 0.01% surfactant concentration

Conclusions

The results presented in this paper allow us to state that drying of a product made of clay-like material containing a prescribed amount of added surfactant considerably reduces the tendency of this material to cracking during intensive drying.

The best quality of the dried samples was achieved for clay saturated with water containing concentration of surfactant equal o slightly below CMC.

The results show that CMC is a parameter having very essential influence on moisture transport inside capillary-porous materials during drying.

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