THESIS SUMMARY

ÉTUDE DU SÉCHAGE CONVECTIF DE BOUES DE STATION D'ÉPURATION - SUIVI DE LA TEXTURE PAR MICROTOMOGRAHIE À RAYONS X

STUDY OF CONVECTIVE DRYING OF WASTEWATER SLUDGES – TEXTURE FOLLOW-UP BY X-RAY MICROTOMOGRAPHY

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Keyword : convective drying, wastewater sludges, X-ray microtomography, moisture profiles, cracks, shrinkage.

This thesis comes within a recent research dynamic in the field of sludge drying, according to European requirements concerning urban wastewater treatment and landfilling of biodegradable materials. Considering landspreading and utilization for energy purposes as the two major issues to eliminate sludges, drying constitutes, in both cases, an essential step after mechanical dewatering. Despite obvious economic, industrial and environmental interests, rather few studies have been devoted to wastewater sludge drying till lately. This work aims to improve the knowledge in the field of sludge drying and to better apprehend the textural changes that occur during drying by using X-ray microtomography.

A first part of the work is dedicated to the development of a method allowing the production of sludge samples with a reproducible dryness, in order to realize the study on real sludges. Sludges are collected after secondary settling and thickening in two domestic wastewater treatment plants near university. Conditioning and mechanical dewatering are realized in the laboratory. Filtration cakes are characterized by different techniques : rheology, sorption isotherms,… Rheological measurements indicate that, for a same sludge, elastic and viscous modulus only depends on the cake dryness. Drying experiments performed on individual cylindrical extrudates obtained from the cake show that operating conditions used for conditioning (polyelectrolyte dose) and dewatering (filtration pressure drop) have no significant influence on drying kinetics.

The next part of the work shows that X-ray microtomography, despite this technique is still few used in chemical engineering, is a choice tool to follow the textural changes of individual samples submitted to convective drying. Contrary to methods traditionally or newly used (caliper, volume displacement methods, NMR,…), X-ray microtomography is a non destructive, accurate and easy to use technique. The analysis of the images obtained by microtomography allows quantifying the shrinkage of the sample, the cracks and the moisture gradients at the sample wall at successive drying levels. The study of the influence of three operating variables (temperature, superficial velocity and absolute humidity of air) on the shrinkage, the development of cracks and moisture gradients is performed in a convective microdryer specially designed in the laboratory. Extragranular heat and mass transfer coefficients, intragranular diffusion coefficient and the water evaporation capacity are estimated from experimental data. A multi-zone analysis proposes to relate the different phenomena observed. Moisture gradients are induced by internal diffusional limitations and cause mechanical stresses. Cracks appear when mechanical stress exceeds the breakage level. Results show clearly that the crack extent depends on the value of the moisture gradients.

The last part of the work deals with a detailed textural characterization of the dried samples. Several characterization techniques (scanning electron microscopy, mercury porosimetry, analysis of N_2 adsorption-desorption isotherms, X-ray microtomography) show that the two sludges considered in the study present very different final textures. 3D images and binary images of cross sections indicate, among others, that the cracks developed during drying have different shapes and configurations. Morphological analysis of these cracks gives some ideas about the way cracks develop and brings to the fore a relation between texture and drying kinetics.

Although the presence of cracks is not of the highest importance for the final quality of dried sludges, the methodology developed in this thesis can be applied to a large variety of other soft materials (food, ceramics,…) for which crack formation has to be avoided because it impairs the final quality of the dried material. In the future, a fully coupled thermo-hydro-mechanical model will be implemented in a Finite Element code to quantify the evolution of the stress tensor versus the drying level especially at the onset of cracks formation. Results obtained in this thesis will allow validating the model.

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