Modelling and Simulation of a Sludge Drying Process

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Alessandro Beghi **Mirco Rampazzo**

Department of Information Engineering, University of Padova, Italy

Abstract

Sewage sludge is an inevitable result of anthropic activity, and its management is an ever-increasing problem. As a result of that, new solutions regarding sludge treatment, management, and utilization are in demand. In this scenario, drying is a non-avoidable step for sludge transformation. In this research, we have developed a dynamic model, as simple as possible but accurate enough, of a convective sludge dryer by means of First-Principle Data-Driven approach and a Matlab-based simulation environment is designed accordingly. Simulation examples show how the model mimics properly certain fundamental aspects of the wastewater sludge behaviour during drying.

Motivation

- The human activities produce millions of sludge and wastewater every year.
- Sludge management is an ever-increasing problem.
- Wastewater treatment plants (WWTP) are continuously increasing.
- Sludge drying is a non-avoidable step in sludge treatments.

Sewage sludge is a residual from anthropic activity.

Sludge wastewater treatment plant (WWTP).

Sewage sludge and its treatment.

Main Objectives

1. Modelling of an innovative convective sludge dryer.
2. Exploiting engineering computational software tools.
3. Development of a Matlab®-based simulation environment.
4. Simulation and analysis of the convective drying process.
5. Design and test convective dryer control strategies within the model-based paradigm.

The Convective Dryer

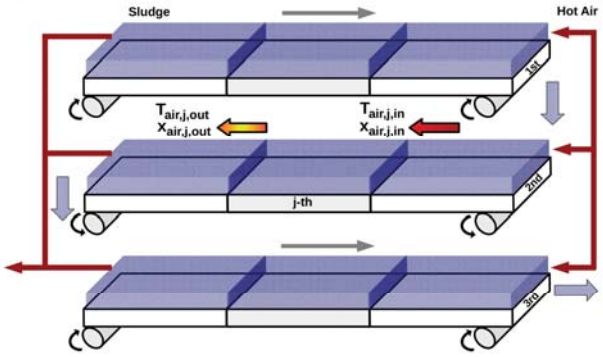
A convective low temperature sludge dryer with multilayer belt is considered. The sludge is provided by a hopper to a conveyor belt, which is divided in three layers placed one above the other. The warm air stream is introduced in the dryer by an air diffuser placed above the first layer of the conveyor belt. The belt alternately moves and stops at regular intervals.

The convective sludge dryer: hopper, multilayer conveyor belt, air diffuser, and burner.

Methods

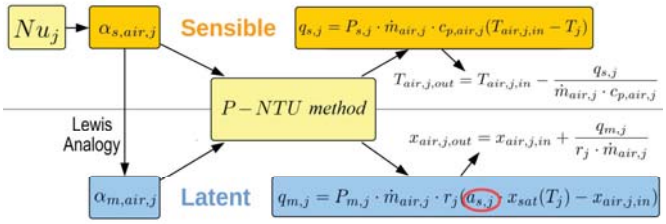
- Modelling: First-Principle Data-Driven (FPDD) approach
  - ✓ knowledge of the physical phenomena;
  - ✓ exploiting available data on the real system.
- Finite volume upwind scheme.

Finite Volume Upwind Scheme



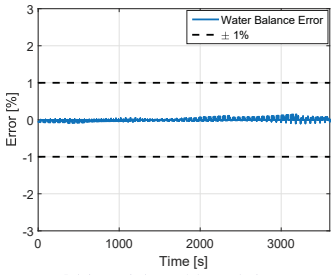
Each of the three layers of the conveyor belt is divided in elements, which constitute the control volumes. The inputs of each element depend on the outputs of the previous one at the previous time instant. The mass and energy balances are considered in the volume element.

Air Properties: Temperature and Humidity

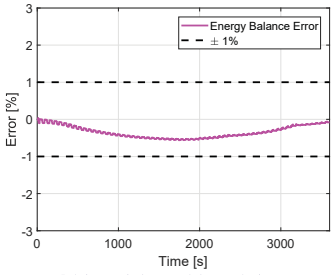


The temperature and the humidity of the air leaving the j-th element have been derived from sensible and latent heat flows. The water activity coefficient, $a_{s,j}$, depends on the material and on the thickness of the sludge layer and it has been obtained by means of experimental data.

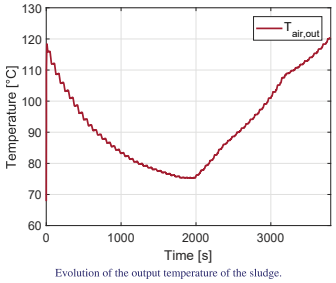
Simulation Results



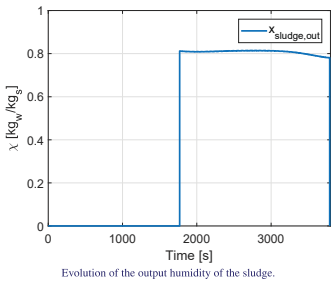
Relative error in the water balance evaluation.



Relative error in the energy balance evaluation.



Evolution of the output temperature of the sludge.



Evolution of the output humidity of the sludge.

Dynamic simulations.

Conclusions

- ✓ A dynamic model of a convective low temperature sludge dryer has been derived.
- ✓ A FPDD approach and a finite volume upwind scheme have been adopted.
- ✓ A Matlab®-based simulation environment has been designed.
- ✓ The simulation environment can be potentially used to design and test dryer control strategies.

Acknowledgements

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