REALISTIC DYNAMIC BLOWER ENERGY CONSUMPTION MODELS FOR ACTIVATED SLUDGE SYSTEMS

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Introduction

One of the main challenges for the optimization of activated sludge systems today is the proper evaluation of all important factors, for instance effluent quality (including priority pollutants), energy consumption and greenhouse gas emissions. At wastewater treatment plants (WWTPs) aeration is the largest energy consumer (Ast et al. 2008, Devisscher et al. 2006, Fenu et al. 2010, Tchobanoglous et al. 2004, Zahreddine et al. 2010). As such aeration energy consumption is an essential factor to be considered in the optimization of activated sludge systems. Despite the increasing level of detail in wastewater treatment process models, oversimplified energy consumption models (i.e. constant “average” power consumption) are being used in optimization exercises (Copp 2002, Gernaey et al. 2006, Martín de la Vega et al. 2013, Rosso and Stenstrom 2005, Wambecq et al. 2013). As these models have the interesting potential to be used in multi-criteria optimization exercises (e.g. optimizing effluent quality, greenhouse gas emissions and operational costs simultaneously), they may lead to poor predictions and their use in optimization could lead to suboptimal operation. Therefor the authors propose a new, dynamic model, based on the same principles as the one they previously successfully applied for pumping applications (De Keyser et al. 2014).

A new dynamic model for a more accurate prediction of aeration energy costs in activated sludge systems, equipped with submerged air distributing diffusers (producing coarse or fine bubbles) connected via piping to blowers, has been developed to overcome this unbalance in the coupled submodels. The objective of the proposed model is to allow for dynamically simulating the power consumed by an aeration system in function of (a) the physical characteristics of the aeration system (i.e. blowers, piping, diffusers), (b) the water height in the aerated tanks and (c) the volumetric air flow rate imposed by a control system. The poster will illustrate that the dynamic model is preferably used in optimisation efforts for energy minimisation.

Materials and methods

Key factors that influence WWTP aeration cost are the type of aeration blower employed, the aeration system configuration (e.g. diffuser types, water head and piping characteristics) and the control strategy implemented on the aeration system. The blowers employed in fine bubble diffuser aeration systems are compressors operating at low relative pressures and can be classified into two broader classes, i.e. centrifugal and positive displacement (PD) types (Henze et al., 2009). To date, three main control strategies are implemented to enable “turn-up” or “turn-down” capacity to these aeration blowers, namely variable Inlet Guide Vane (IGV) control, Outlet Throttling (OT) control and Variable Frequency Drive (VFD) control.

Key issues to be considered when evaluating the energy consumption of aeration systems are: (1) energy requirement for compression, (2) inlet conditions of the air, (3) system characteristic curve, (4) blower characteristic curve, (5) blower efficiency and (6) the type of process control strategy employed.

Results and discussion

The developed model will be further explained in the poster. The model is demonstrated for the aeration system at the Mekolalde WWTP (originally designed to treat wastewater of 40,000 PE) located in Bergara (Guipúzcoa, Spain). This system uses a positive displacement blower (PD blower Mapner SEM.40TR). After calibration the model proved to give an accurate prediction of the real energy consumption by the blowers (Figure 1). Comparison was made with constant average power consumption (a fixed ratio power consumption over flow rate) models and it was shown (Figure 2) that the dynamic model captures the trends better than the constant average power consumption.

Conclusions

A new dynamic model for a more accurate prediction of aeration energy costs in activated sludge systems, equipped with submerged air distributing diffusers (producing coarse or fine bubbles) connected via piping to blowers, has been developed and demonstrated. The new model proved to give an accurate prediction of the real energy consumption by the blowers and captures the trends better than the constant average power consumption models currently being used. This clearly illustrates, also because the cost of energy depends on peak demand values, that the dynamic model is preferably used in multi-criteria optimization exercises for minimizing the energy consumption.

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Figures and tables

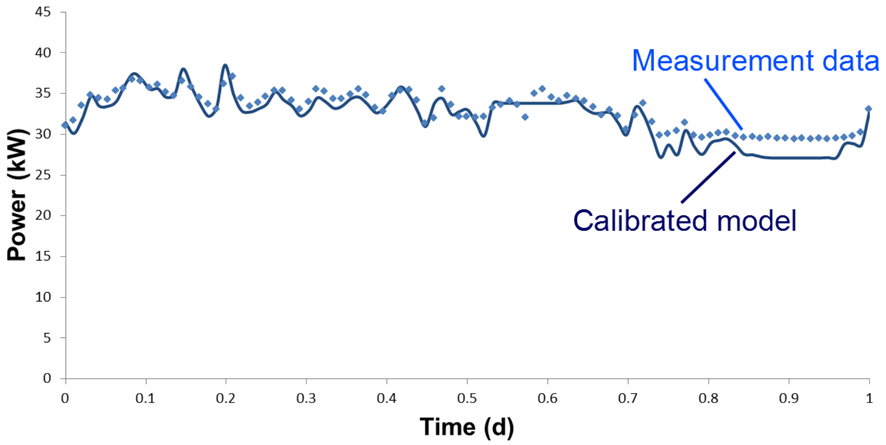

Figure 1. The calibrated dynamic model (dark blue line) show a close fit to the measurement data (blue dots), including the trends.

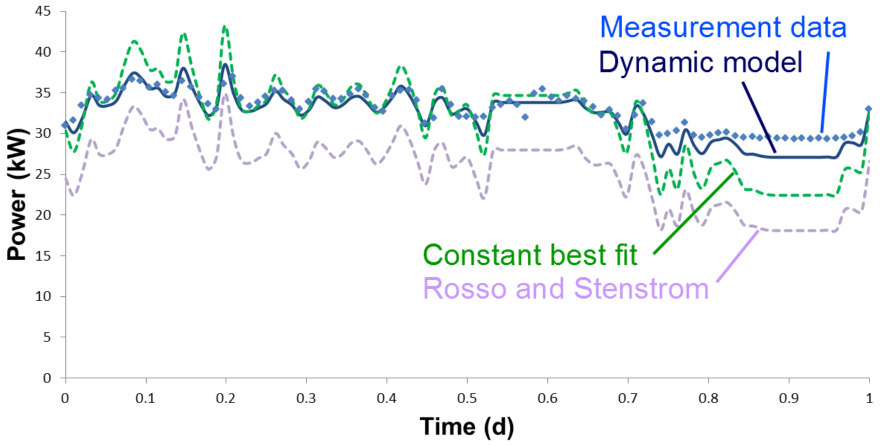

Figure 2. The dynamic model (dark blue line), describes the measurement data (blue dots) and its trends better than the models with constant average power consumption ratios. Both the model by Rosso and Stenstrom (2005) (purple dashed line) and the model with the best fit for the average of the data (green dashed line) show larger variations.