Intelligent Control of Waste Incineration Plants

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Introduction

Incineration is currently used to dispose of various waste streams including municipal, hazardous and illicit waste. Benefits can be found from the reduction in waste volume, destruction of hazardous constituents and the energy that is recovered from the process. Pollution may effectively be controlled to within acceptable limits, although improvements are constantly being made.

Gas clean-up technologies and the control systems that they interface with are continuously undergoing improvements to deal with more stringent regulations. Inefficient control at the incineration stage can place a drain on the gas clean-up and air quality treatment systems, which inevitably leads to a degradation in overall performance. This can result in emissions over emission constraints and higher maintenance costs as the system is more frequently operated to its limits.

Multi-Objective Optimisation of an MSW Incinerator

One of the primary objectives of the operation of an incineration plant is to maximise throughput. However, increasing throughput can intensify the loading on the gas-clean-up system and also cause a violation of operational constraints. This may result in costly setbacks due to excessive pollution emissions and the need for increased emissions controls. Therefore a multi-objective strategy is required to optimise plant operation in terms of economic goals and environmental and operational constraints.

This section presents an off-line optimisation scheme, using a Multi-Objective Genetic Algorithm (MOGA), for a waste incineration plant, which will allow certain parameters to be adjusted for maximum throughput, while keeping within emissions and operational constraints. The optimisation procedure is independent of both plant construction and waste ash output and is applied in this case to the model of a municipal solid waste incineration plant, incorporating a moving grate.

FLIC Modelling

Fluid dynamic incineration Code (FLIC) is an incinerator burning bed software simulation package based on a fundamental mathematical model.

A wide range of different real-world incineration plants can be represented in the model.

FLIC can generate prediction values for a range of output variables.

Computational time is too long (45-60 minutes for one set of solutions) for direct use in a search.

A range of data can be generated for use in a full-scale modelling approach that can interpolate between the data points.

Unconstrained Optimisation

An unconstrained optimisation has been carried out to find plant settings that both maximise carbon-in-ash and minimise waste feed rate.

A range of Pareto-optimal decisions have been found that a human operator may choose between based on current desired performance.

MOGA Optimisation

The MOGA is a directed evolutionary search algorithm, which is based on the Damierian principle of survival of the fittest.

A population of points are propagated, which allows the problem domain to be searched in parallel.

An objective function, F(x), is used to evaluate the performance of candidate solutions, which may be comprised of multiple decision variables, X seeking to satisfy multiple objectives.

The technique of Pareto-optimal ranking ensures the survival of individuals, X, that are fit in all objective categories.

Dynamic Modelling of a Hazardous Waste Thermal Treatment Plant

A hazardous waste thermal treatment facility must be designed with highly constrained conditions to ensure Environment Agency compliance for safe waste disposal. The Auto-Regressive model is used as a multi-objective optimisation procedure to define specific operating conditions, which can then be used to find optimal solutions while keeping within operational constraints. Data from a UK hazardous waste thermal treatment plant has been collected to establish a starting algorithm procedure.

This section presents results from using linear dynamic modelling techniques. The inputs have been sub-divided on the basis of steady-state effects, discrete instantaneous transients and continuous transients. A single input single output model has been extracted from the available data coupling burner fuel flow and air flow. The resulting model is suitable for use in a control system design application.

Neural Network Modelling Results

Linear Dynamic Modelling

A black box procedure can be used to model the dynamics of a system.

A common structure is that of ARX (Auto-Regressive with exogenous inputs).

The ARX model assumes that future outputs of the system can be described by a linear combination of past inputs and outputs.

Auto-Regressive (Output description with eXogenous Inputs (e.g. fuel and combustion air))

\[ y(t) = a_0x(t-1) + a_1x(t-2) + \ldots + a_nx(t-n) + b_0u(t) + b_1u(t-1) + \ldots + b_nu(t-n) + c(t) \]

Conclusions

A static optimisation method, using multi-objective genetic algorithms, has been developed that gives the human operator a wide choice of Pareto-optimal decisions for running the plant.

Linear dynamic models have been developed that can be utilised in an optimisation control systems design.

Future work has been motivated in the areas of non-linear dynamic modelling, due to the increasing capability of linear models to cope with certain aspects of the plant dynamics.

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