4.2.3 Use of designed experiments

Description

Experiments may be used to investigate the effect of design features. Various parameters may be investigated including gas distributions, different temperature settings, variation in fuel analysis including moist, inside the furnace and boiler and in different support systems. It can be projected as a real world counterpart to simulation techniques with an accurate local response surface model approximation of the partial differential equations based on real data estimates of combustion parameters. Designed experiments can be used to predict gas flows, local temperatures, flue gas emission characteristics including NOx and CO levels, and ash analysis.

In operating plants with big data flows and millions of parameter setting permutations it is an indispensable tool for process optimization.

A series of multifactor experiments where up to forty factors are varied simultaneously in balanced designs have been illustrated to be very effective. The experiments are designed to produce data to solve specific problems as efficient as possible. These problems can be optimization of NOx level given a low stable CO level and low dust levels. Both response mean levels and response variations can be optimized simultaneously.

Designed Experiments has been successfully used at existing incineration plants to:

modeling the effects of flue-gas re-circulation and reagent injection for SNCR NOX, upgrading thermal boiler power given emission requirements.

Environmental benefits

The optimization of furnace settings has the potential to enhance the combustion performance and therefore limit the formation of CO, TOC, PCDD/F and/or NOX (i.e. combustion related species). In addition, the NOx mean level can be minimized given a low and stable CO level, low dust levels and high thermal efficiency/ low CO_2 emissions. The probability of success increases with the knowledge of plant characteristics and number of experiment adjustment parameters.

Improvement in performance of abatement equipment.

Cross-media effects

Improving performance at the combustion stage may allow the selection of gas cleaning equipment with reduced emissions and consumptions.

Operational data

The improvements of the flue-gas flow distribution along the boiler helps to reduce erosion and fouling leading to corrosion.

Applicability

The technique is applicable to:

- new waste incineration projects in combination with multiphysics simulation
- final commissioning testing stages
- to optimize design of existing plants where concerns exist regarding the combustion and support systems interactions
- to simultaneously optimize multiple combustion responses e.g. NOX, CO, SO2, CO2 (efficiency).
- to most process optimization problems encountered in the operating phase i.e. not only combustion processes (ref ISO 9000 / ISO 14000 statistic quality control and statistically designed experiments).

Economics

A typical designed experiment optimization project is structured in a sequence of two to three experiments, each with eight or more factors, 16 or more runs and 2 or more responses. These experiments are frequently performed during normal operation with minor restrictions. Typical a project cost could be in the range of EUR 10000 to 100000, depending on the scope of the study and the number of experiments required. Extra ordinary costs associated with the plant being offline, by accidently tripping plant or damage to equipment due to exotic operational settings, are not included.

Savings in investment and operational costs may arise from:

- Improve specifications prior to rebuilt, retrofit or modification of boiler in use
- selection of alternative abatement system technology options
- smaller/less complex abatement systems with higher reliability and availability, in rare cases optimization to replace abatement systems
- lower consumptions by the abatement system
- lower emission levels and emission fees (e.g. NOx) where applicable
- higher thermal efficiency reducing CO2 emission level / MWout.
- If implemented in site organization: Higher operational efficiency due to improved root cause analysis and optimization routines
- If implemented in site organization: More efficient operational organization building plant operational knowledge more rapidly

Significant costs savings can be associated with modifying the furnace or boiler design of existing installations.

Driving force for implementation

Powerful optimization routines in complex process settings with multiple emission responses replace investment in hardware with plant knowledge. Increased combustion efficiency. Increased efficiency in operational routines. Design of experiments is a universal process optimization tool (ref ISO 9000 / ISO 14000). Implementation in site organizations increases overall plant operation efficiency including mean BAT process performance.

Example plants

The technique has been used at:

Fortum Högdalen plant boiler one and three.

Reference

[01,FAKTORFÖRSÖK, NOXSTYRANDE FAKTORER HÖGDALEN PANNA 1, Rev 940212],

[02, Rapport HDL IT1 Kontrollerad Effekthöjning P1P2 rev 1, 2006-06-04],

[03, Rapport HDL IT2 Kontrollerad Effekthöjning P1P2,2006-09-06]