

Process Safety and Environmental Protection

rok 2014, ročník 92

Číslo 3 (May 2014)



Lei Pang, Tong Wang, Qi Zhang, Qiuju Ma, Lu Cheng. *Nonlinear distribution characteristics of flame regions from methane-air explosions in coal tunnels.* Pages 193–196.

High temperature flame fronts generated in methane-air explosions are one of the major hazards in underground coal mines. However, the distribution laws of the flame region in explosions of this type and the factors influencing such explosions have rarely been studied. In this work, the commercial software package AutoReaGas, a finite-volume computational code for fluid dynamics suitable for gas explosion and blast problems, was used to carry out numerical simulations of a series of methane-air explosion processes for various initial premixed methane-air regions and cross-sectional areas in full-scale coal tunnels. Based on the simulated results and related experiments, the mechanism of flame propagation beyond the initial premixed methane-air region and the main factors influencing the flame region were analyzed. The precursor shock wave and turbulence disturb the initial unburned methane-air mixture and the pure air in front of the flame. The pure air and unburned mixture subsequently move backward along the axial direction and mix partially. The enlargement of the region containing methane induces that the range of the methane-air flame greatly exceeds the initial premixed methane-air region. The flame speed beyond the initial region is nonzero but appreciably lower than that in the original premixed methane-air region. The length of the initial premixed methane-air region has substantial influence on the size of the flame region, with the latter increasing exponentially as the former increases. For realistic coal tunnels, the cross-sectional tunnel area is not an important influencing factor in the flame region. These conclusions provide a theoretical framework in which to analyze accident causes and effectively mitigate loss arising from the repetition of similar accidents.

- **Keywords:** Gas explosion; Flame propagation; Tunnel; Shock wave; Temperature

Huosheng Li, Shaoqi Zhou, Guotao Huang, Bin Xu. *Achieving stable partial nitritation using endpoint pH control in an SBR treating landfill leachate.* Pages 199-205.

The feasibility of using endpoint pH control to achieve stable partial nitritation (PN) in an SBR for landfill leachate treatment was investigated. By imposing a fixed-time anoxia followed by variable-time aeration in an SBR cycle, successful partial nitritation was maintained for 182 days at a nitrogen loading rate of 0.30–0.89 kg/m³/day. The effluent NO₂⁻-N/NH₄⁺-N ratio and the effluent NO₃⁻-N concentration were 1.30 ± 0.22 and 16 ± 9 mg/L, respectively. High free ammonia (FA) and low dissolved oxygen (DO) concentrations were inhibition factors of nitrate formation. The termination of aeration at a suitable endpoint pH was the key to achieve an effluent NO₂⁻-N/NH₄⁺-N ratio close to

the stoichiometric value. This endpoint pH control strategy represents practical potentials in the engineered application of combined PN–ANAMMOX processes.

- **Keywords:** Partial nitritation; ANAMMOX; Denitrification; Landfill leachate; SBR

Yahya Chetouani. *A sequential probability ratio test (SPRT) to detect changes and process safety monitoring. Pages 206-214.*

Detecting anomalies is an important problem that has been widely researched within diverse research areas and application domains. The early detection of faults may help avoid product deterioration, major damage to the machinery itself and damage to human health. This study proposes a robust fault detection method with an Artificial Neural Network-Multi-Layer Perceptron (ANN-MLP) and a statistical module based on Wald's sequential probability ratio test (SPRT). To detect a fault, this method uses the mean and the standard deviation of the residual noise obtained from applying a NARX (Nonlinear Auto-Regressive with eXogenous input) model. To develop the neural network model, the required training and testing data were generated at different operating conditions. To show the effectiveness of the proposed fault detection method, it was tested on a realistic fault of a distillation plant at the laboratory scale.

- **Keywords:** Safety; Reliability; Fault detection; SPRT; ANNs; Distillation column

Yahya Chetouani. *Model selection and fault detection approach based on Bayes decision theory: Application to changes detection problem in a distillation column. Pages 215-223.*

The fault detection of industrial processes is very important for increasing the safety, reliability and availability of the different components involved in the production scheme. In this paper, a fault detection (FD) method is developed for nonlinear systems. The main contribution consists in the design of this FD scheme through a combination of the Bayes theorem and a neural adaptive black-box identification for such systems. The performance of the proposed fault detection system has been tested on a real plant as a distillation column. The simplicity of the developed neural model of normal condition operation, under all regimes (i.e. steady-state and unsteady state), used in this case is realised by means of a NARX (Nonlinear Auto-Regressive with eXogenous input) model and by an experimental design. To show the effectiveness of proposed fault detection method, it was tested on a realistic fault of a distillation plant of laboratory scale.

- **Keywords:** Fault detection; Reliability; Safety; Classification; Bayes theorem; Neural networks; Dynamic systems; Distillation column

Babak Kavianpour, Alireza Shariati, Mahmood Moshfeghian. *Thermodynamic investigation and hydrate inhibition of real gas flow through orifice during depressurization. Pages 224-230.*

A thermodynamic procedure has been proposed which can be used to predict the gas pressure, temperature and flow rate through orifice upon chock flow condition, using equation of state (EOS). The procedure applied for emergency depressurization operation incorporating the Peng-Robinson EOS and validated by comparing flow rates of a multi-component hydrocarbon gas mixture for thirteen experimental cases. The average absolute deviations of the predicted flow rates for orifice discharge coefficients of 0.85 and 0.9, are 7.36% and 2.03%, respectively. The corresponding error for API 520 (American Petroleum Institute Recommendation Practice 520) method is 6.91%. In this work, the hydrate formation temperature and hydrate inhibitor type and its required weight fraction for preventing the hydrate formation upon orifice and its upstream

conditions are evaluated by the EZ-Thermo software using the Moshfeghian–Maddox method. The results qualitatively show that the hydrate prevention is essential for the safety of the operation due to low temperature condition.

- **Keywords:** Fault detection; Reliability; Safety; Classification; Bayes theorem; Neural networks; Dynamic systems; Distillation column

A. Azadeh, V. Salehi, B. Ashjari, M. Saberi. *Performance evaluation of integrated resilience engineering factors by data envelopment analysis: The case of a petrochemical plant.* Pages 231-241.

Petrochemical units are potentially prone to incidents that have catastrophic consequences such as explosion, leakage of toxic materials, and the stoppage of the production process. Resilience engineering (RE) is a new method that can control incidents and limit their consequences. It includes top-level commitment, reporting culture, learning, awareness, preparedness, and flexibility. However, this study introduces a new concept of RE (referred to as integrated RE or IRE) which includes the above factors in addition to self-organization, teamwork, redundancy and fault-tolerant. This study evaluates performance of IRE in a petrochemical plant through considering the obtained data from questionnaires and data envelopment analysis (DEA) approach. Moreover, the performance of RE and the new IRE are compared and discussed. The results show that although there is a strong direct correlation between the DEA results in two frameworks, the mean scores of efficiency in IRE is slightly higher than RE. This is the first study that introduces an integrated approach for RE. In addition, this study is amongst the first ones that examine the behavior of resilience engineering by DEA. Moreover, the superiority of IRE is shown through robust statistical analysis.

- **Keywords:** Fault detection; Reliability; Safety; Classification; Bayes theorem; Neural networks; Dynamic systems; Distillation column

Giacomo Antonioni, Daniele Guglielmi, Valerio Cozzani, Carlo Stramigioli, Davide Corrente. *Modelling and simulation of an existing MSWI flue gas two-stage dry treatment.* Pages 242-250.

Power generation from municipal solid waste incineration (MSWI) is in widespread use as a technology for solid waste treatment and energy recovery. One of the main environmental issues posed by MSWI plants is the continuous emission of pollutants into the atmosphere. Among flue gas components, acid gases are of particular concern due to their high potential impact on the environment. The two-stage dry treatment is among the Best Available Technologies for an enhanced removal efficiency of acid gases. In the first stage the removal process is based on the reaction of acid gases with solid calcium hydroxide (slaked lime), while in the second stage removal is obtained by reaction with sodium bicarbonate. In the present study, design and process data from an existing Municipal Solid Waste Incinerator, where a flue gas two-stage treatment is adopted, were used to test a previously developed operational model. The model was implemented in a simulation software to describe both design and process conditions, taking also into account the recycle rate of solid products and unreacted calcium hydroxide in the first stage. Simulations were carried out with the aim of optimizing both reactant feed rates and amounts of solid wastes formed in the acid gas removal process.

- **Keywords:** Waste incineration; Flue-gas treatment; MSWI; Acid gases removal; Process modelling

Chen Qinqin, Qian Jia, Zengwei Yuan, Lei Huang. *Environmental risk source management system for the petrochemical industry*. Pages 251-260.

We identify environmental risk sources within the petrochemical industry with a bow-tie analysis, evaluate environmental risk sources with an integrated environmental risk assessment index, and classify environmental risk sources considering both environmental consequences and management costs. Furthermore, we develop a routine management system for environmental risk sources based on browser/server model and web-GIS technology. The system has four main functions: petrochemical enterprise registration and declaration, environmental risk source information correction and confirmation, environmental risk source evaluation and classification, and environmental risk source management. The system runs with the following sequential steps. (1) Petrochemical enterprises register and declare their environmental risk source information. (2) The registered environmental risk source information is checked, corrected and confirmed by local environmental officials. (3) The probability and intensity of environmental risk are calculated for all registered petrochemical factories. (4) All environmental risk sources are classified into high, medium and low risk sections based on their potential regional environmental and ecological impacts. (5) The system provides recommendations on the routine risk management based on empirical expert opinions. The software provides an effective tool for safety production of petrochemical enterprises and can be applied by local governments for environmental risk source management.

- **Keywords:** Petrochemical industry; Bow-tie analysis; Environmental risk source; Environmental risk assessment; Environmental risk management

Ginesta Rodriguez, Antonio D. Dorado, Marc Fortuny, David Gabriel, Xavier Gamisans. *Biotrickling filters for biogas sweetening: Oxygen transfer improvement for a reliable operation*. Pages 261-268.

An industrial-scale biotrickling filter for the removal of high concentrations of H₂S is described in this work. The system has been operating at H₂S inlet concentrations between 1000 and 3000 ppm_v at acidic conditions. A decrease of pH from 2.6 to 1.8 did not affect the biological activity inside the biofilter while reducing the water make-up consumption up to 75%. The current oxygen supply system, based on direct injection of air to the liquid phase, has demonstrated to be inefficient for a long-term operation leading to elemental sulfur accumulation in the packing material (i.e. promoting clogging episodes). The present study demonstrates it is possible to partially remove (40.3%) the deposited elemental sulfur by bio-oxidation when biogas is not fed. In normal operation conditions, the implementation of an aeration system based on jet-venturi devices has shown quite promising results in terms of oxygen transfer efficiency and robustness. Such improvement of oxygen transfer was translated in a better conversion of H₂S to sulfate, which increased around 17%, prolonging the lifespan operation at low-pressure drop.

- **Keywords:** Petrochemical industry; Bow-tie analysis; Environmental risk source; Environmental risk assessment; Environmental risk management

Reza Eslamipoor, Abbas Sepehriar. *Firm relocation as a potential solution for environment improvement using a SWOT-AHP hybrid method*. Pages 269-276.

Global economic expansion and increasing concentration of people in the large cities, especially in developing countries leads to some environmental issues such as air pollution. Relocation of the firms as a great air pollutant can be an appropriate alternative for diminishing these pollutions. Yet, there is a lack of research about factors precluding firm relocation with respect to decision making factors when determining whether or not to relocate. Thus, the purpose of this case study is to examine firm relocation decision-making factors and to apprehend the role of environment issues in making them using a combination of SWOT matrix and Analytic Hierarchy Process (AHP). The combination yields analytically determined priority factors and makes them commensurable. The results indicated that decision makers at this firm consider weaknesses, more importantly than strengths, opportunities and threats. Specifically, eradicating from a large market is the most significant factor for decision makers and notably diminishing air pollution as a governmental concern ranked third.

- **Keywords:** Air pollution; Firm relocation; AHP; Decision making; SWOT