Available online at www.sciencedirect.com
ScienceDirect
Fuzzy Sets and Systems 161 (2010) 2597–2611
FUZZY sets and systems
www.elsevier.com/locate/fss

An application of neuro-fuzzy technology for analysis of the CO_2 capture process

Qing Zhou[a], Christine W. Chan[a,*], Paitoon Tontiwachwuthikul[b]

[a] *Energy Informatics Laboratory, Faculty of Engineering and Applied Science, University of Regina, Regina, Saskatchewan, Canada S4S 0A2*
[b] *Process Systems Engineering Laboratory and International Test Centre for C O 2 Capture (ITC), University of Regina, Regina, Saskatchewan, Canada S4S 0A2*

Received 29 October 2009; received in revised form 14 March 2010; accepted 27 April 2010
Available online 6 May 2010

Abstract

The objective of this paper is to study the relationships among the significant parameters impacting carbon dioxide (CO_2) production. An enhanced understanding of the intricate relationships among the process parameters enables prediction and optimization, thereby improving efficiency of the CO_2 capture process. Our work adopted a fuzzy logic approach that explores the relationships among the parameters involved in the amine-based post combustion CO_2 capture process at the International Test Centre for CO_2 Capture (ITC) located in Regina, Saskatchewan of Canada. The key process parameters were selected based on a review of relevant literature and interviews with experts. The adaptive-network-based fuzzy inference system (ANFIS) technique was trained with historical data and generated the membership functions and rules which best interpret the input/output relationships in the process. Four fuzzy inference systems were independently developed for four output parameters, each of which consists of four inputs and 144 rules. The model validation process showed that modeling accuracies of these fuzzy inference systems are within acceptable limits. The developed fuzzy inference systems constitute a knowledge base on the parameters involved in the CO_2 capture process, and can be further expanded and improved for prediction and optimization of the CO_2 capture process in the future.

Keywords: CO_2 capture process; Neuro-fuzzy systems; ANFIS

1. Introduction

Carbon dioxide (CO_2) is one of the important greenhouse gases (GHG) responsible for about 70% of the enhanced greenhouse effect and global warming, which has already caused serious climate changes such as rising sea levels, flooding of coastal cities, severe drought conditions in inland regions, and species endangerment. Combustion of fossil fuels in power generation and in various industrial processes such as cement manufacture and hydrogen production is responsible for contributing large amounts of CO_2. Due to increasing public concerns about environmental pollution and global warming, the post combustion CO_2 capture technology is commonly adopted for reducing industrial CO_2 emissions. The research on post combustion CO_2 capture has been ongoing in the last two decades, and its primary

* Corresponding author. Tel.: +1 306 585 5225; fax: +1 306 585 4855.
E-mail address: christine.chan@uregina.ca (C.W. Chan).

0165-0114/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.fss.2010.04.016

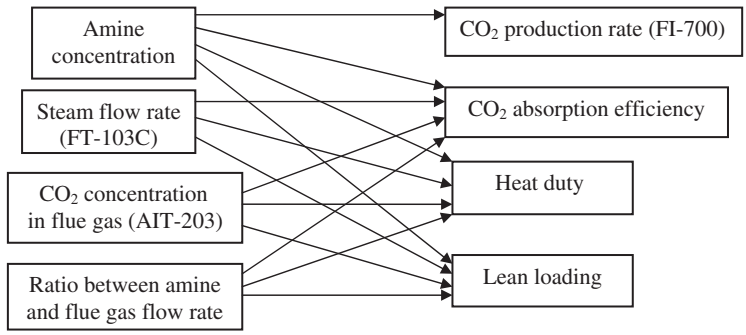

Fig. 1. Relationships between the selected process parameters.

objective is to improve efficiency of the CO_2 capture process using different approaches while reducing specific operating problems such as solvent degradation and corrosion.

In order to improve efficiency of the CO_2 capture process, a good understanding of the intricate relationships among the parameters involved in the CO_2 capture process is necessary. Hence, the objective of the work is to uncover the most critical process parameters which directly influence the performance of the CO_2 capture system and quantify their influences. The critical process parameters are listed in Fig. 1. The four independent or input parameters are listed on the left side and the four dependent or output parameters are listed on the right side of the figure. And the arrows indicate the direction of influence from the input to the output parameters. The objective of our research is to study the influence of the input to the output parameters. If the quantitative influence of each key process parameter is determined, the plant performance and process efficiency can be predicted based on the values of the key input process parameters. If the predicted performance is not satisfactory, the independent parameters related to the dependent parameter in question can be changed. Therefore, efficiency of the CO_2 capture process can be improved by tuning the process parameters identified in these relationships.

The objective of this research is to study the nature of relationships among the key parameters of the process. From a review of the relevant literature, we observed that the most significant parameters reflecting plant performance and efficiency include CO_2 production rate, heat duty, lean loading, and CO_2 absorption efficiency. The parameters influencing these key parameters include amine solvent concentration, amine circulation rate, steam flow rate, CO_2 concentration in flue gas, and flow rate of the flue gas. In our study on relationships among the process parameters, the experimental data collected from the amine-based post combustion CO_2 capture process at the International Centre of CO_2 Capture (ITC) located in Regina, Saskatchewan of Canada from year 2003 to 2006 were analyzed using the approach of neuro-fuzzy modeling. By applying the adaptive-network-based fuzzy inference system (ANFIS), four Sugeno type fuzzy inference systems were developed for modeling the parameters' relationship. The model validation process showed high accuracy of the fuzzy modeling, and the generated rule-base can be used for prediction of the plant performance and optimization of the CO_2 capture process in the future. This paper describes the modeling and analysis procedure, and discusses the results from this method. The paper is organized as follows: Section 2 presents the background literature relevant to the study of the parameters of the CO_2 capture process, the neuro-fuzzy technique, and the applications of the ANFIS method. Section 3 presents the architecture and learning algorithm of an ANFIS model. Section 4 describes the problem domain. Section 5 describes the details of the implementation procedures. Section 6 explains the results and gives some discussion. Section 7 gives a conclusion and some discussion of our future work.

2. Literature review

2.1. Previous studies on parameters of CO_2 capture process

The study of the CO_2 capture process has been focused on the four key parameters useful for evaluating the process efficiency and plant performance: heat duty, lean loading, CO_2 absorption efficiency, and CO_2 production rate. Zhou et al. [1] conducted a statistical study in Statistical Package for the Social Science (SPSS) to analyze the process parameters by first examining the correlation among the parameters, and only the ones which showed significant