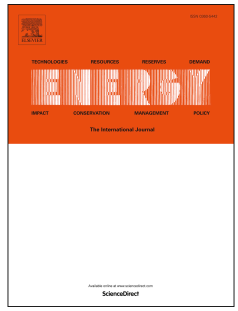
Accepted Manuscript



An artificial intelligence based approach to predicting syngas composition for downdraft biomass gasification

Ali Yener Mutlu, Ozgun Yucel

PII: S0360-5442(18)31895-4

DOI: 10.1016/j.energy.2018.09.131

Reference: EGY 13825

To appear in: *Energy*

Received Date: 21 July 2018

Revised Date: 15 September 2018

Accepted Date: 19 September 2018

An Artificial Intelligence Based Approach to Predicting Syngas Composition for Downdraft Biomass Gasification

Ali Yener Mutlu[1*], Ozgun Yucel[2]

[1]*Department of Electrical and Electronics Engineering, Izmir Katip Celebi University, Izmir, Turkey*
[2]*Department of Environmental Engineering, Izmir Katip Celebi University, Izmir, Turkey*

[*]*aliyener.mutlu@ikc.edu.tr*

ABSTRACT: Artificial neural networks and artificial intelligence based regression techniques have been recently applied to various gasification processes. Although these techniques obtain relatively satisfactory results for predicting gasification products, most of the proposed models are prone to low number of samples in the training data sets, which also lead to over-fitting problem. Furthermore, these models may fall into local minima since cross-validation has never been used for predicting gasification products. In this paper, we consider prediction of gasification products as a classification problem by using machine learning classifiers. Two types of classifiers have been proposed, i.e., binary least squares support vector machine and multi-class random forests classifiers, for predicting producer gas composition and its calorific value obtained by woody biomass gasification process in a downdraft gasifier. The proposed approaches have been developed and tested with 5237 data samples using 10-fold cross-validation, where binary and multi-class classifiers achieved over 96% and 89% prediction accuracy values, respectively.

1. INTRODUCTION

As a result of increasing energy demand and environmental awareness, distributed and decentralized electricity generation is crucial and gaining importance. Conventional power stations are centralized and often require electric energy to be transmitted over long distances. On the contrary, localized and small-scale electricity generation from renewable energy sources such as biomass, biogas, solar power and wind power increasingly play an important role for the electric power distribution system.

As a promising technology, gasification is an effective thermochemical conversion process, which transforms solid biomass into combustible gases, i.e., mixture of hydrogen, methane, carbon monoxide, carbon dioxide, light hydrocarbons and char [1]. The produced gaseous mixture, referred to as syngas, can then be used directly as a gaseous fuel or can be further processed to produce electricity and to generate heat. Furthermore, gasification converts low-value feedstocks into valuable forms of energy since it enables energy production from non-conventional feeds like forest waste, agricultural waste, poultry waste, and municipal solid waste [2].

Fixed bed gasifiers that produce syngas are the oldest and widely studied reactors due to their easy construction and simple operation [3]. The fixed bed gasification systems are classified as updraft, downdraft and crossdraft gasifiers. Downdraft gasifiers have the advantage of yielding lower tar content (1-2 g/Nm3) compared to other fixed bed gasifiers. For this reason, they do not require high cost gas cleaning units and are suitable for small-scale applications. In a downdraft gasifier, it has been proved that a number of chemical reactions take place while solid fuels move together with air in downward direction. Mathematical models that describe dynamic behavior of fixed bed gasifiers can facilitate designing cost effective processes to reduce time and expense of complicated and time consuming experiments.

Limited numbers of kinetic mathematical models, which evaluate possible homogeneous and heterogeneous reactions, have been developed for evaluating the effect of operating conditions on syngas composition and calorific value during gasification process [3], [4]. However, these mathematical models deal with transport (heat, mass and momentum) and kinetic equations leading to extensive efforts for formulation. Therefore, finding the solution of these models is a time consuming and iterative process.

Computational Fluid Dynamics (CFD) can also be used for modeling ‘reacting flow systems’ such as combustion chemical reactors and other mixing processes [5], [6]. So CFD and thermodynamic equilibrium models with limited number of reactions have also been developed for biomass gasification but these models are more appropriate to describe fluidized bed gasifiers rather than fixed bed gasifiers [7], [8].

Thermodynamic equilibrium approach is one of the most widely studied modeling techniques for simulating biomass gasification and can be divided into two sections: the stoichiometric and non-stoichiometric equilibrium methods. The non-stoichiometric method is based on Gibbs free energy minimization [9]–[11]. On the other hand, in the stoichiometric method, the equilibrium is determined by using the equilibrium constants for some particular reactions including water gas shift and methanation [12]–[15]. Both techniques are simple and fast but the equilibrium condition in the gasifiers is never achieved, especially for fixed bed gasifiers.

Artificial neural networks (ANN) are widely used for signal processing, function approximation, simulation, and recognition of patterns [16]. However, ANNs have been rarely used for biomass gasification since they require data sets consisting of large number of samples [17]. Hence, contrary to fluidized beds, the use of ANNs for modeling downdraft biomass gasification is very limited [18]–[20].