Chapter 58

Energy and Exergy Analysis on Gasification Processes: A Preliminary Approach

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ABSTRACT

In recent years, attention has focused on exergy analysis, a type of thermodynamic analysis which is an important tool for the efficiency assessment and the processes optimization when dealing with energy conversion and, particularly, thermochemical processes such as gasification. Thus, this chapter aims to introduce the fundamental concepts of energy and exergy and describe the energy and exergy evaluation tools, elucidating its importance for calculations applied to gasification processes. A case study was performed to show the proposal of energy and exergy analysis. Therefore, a single global gasification chemical reaction was used to represent the gasification process. This analysis can provide a tool to assess and develop models, simulations, calculations, and to optimize real gasification processes. Information and experiences covered in this chapter help to be put into perspective the technology, research and overcoming of challenges.

INTRODUCTION

Gasification technology has been given a lot of attention in these recent years through the analyses of the first and second laws of thermodynamics as an alternative for biomass and waste processing, a way for obtaining global thermodynamic efficiencies, and even for many purposes, such as biological, chemical, thermal and mechanical processes.

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Efficiency estimates from the First and the Second Law of Thermodynamic and also from thermodynamic global analyses of thermal schemes using coal, firewood and biomass residue in gasification and combustion processes, are reported in the literature (Abuadala et al., 2010; Cortez & Gómez, 1998; McKendry, 2002; Park et al., 2014; Rodrigues & Gaggioli, 1980; Singh, Weil, & Babu, 1980; Tiangco, Jenkins, & Goss, 1990).

Generally these thermodynamic analyses are directed to the identification of major points of low thermodynamic efficiencies; in other words, identify the points of great energy waste and/or with larger exergy destruction. The balances and analyses reports of First and Second Law of Thermodynamic as well as exergy efficiency analyses, allows the improvement of thermodynamic processes and cycles. However, a detailed evaluation through thermodynamic specific tools for gasification processes, considering the process in its thermochemical nature, has not yet been verified.

This chapter is divided in two sections. The first section begins with a review about concepts of First and Second Law of Thermodynamics. This section is particularly important to introduce the main concepts to understand the energy and exergy methodology proposed to evaluate the gasification process. In the second section will be presented the thermodynamic study based on combined analyses of First and Second Law of Thermodynamic for a continuous biomass gasification process, considering that the process occurs under only one specific global thermochemical reaction. Two equilibrium models are then proposed for the global equilibrium reaction, both based on the chemical reactions stoichiometry, a first model based in the theoretical gasification reaction, and a second one based in the actual gasification reaction. Estimations are made for the energy and exergy stream flow, the First Law Efficiency (cold and hot), the associated irreversibilities with the theoretical and actual process and the exergy or the Second Law Efficiency. The calculation methodology used it is based on an algorithm that considers balances of mass, energy and exergy on the gasification thermochemical reaction.

Before modelling the single reaction of biomass gasification proposed in this study, it is needed to start a discussion on the different methodologies based on kinetic, thermodynamic and stoichiometric models of chemical reactions involving the development of physical-chemical processes. Through to kinetic models, which are highly rigorous, it is possible to known what occur during the chemical reaction; investigate a nature of the reaction systems and phenomena; understand as the chemical links are formed and broken and estimate the involved energy, among others. On the other hand, the equilibrium models based in the thermodynamic are less rigorous, but no less simple. On a chemical reaction systems it is possible to get the molar concentrations reached at equilibrium, without consider the reaction mechanisms established by the kinetic. Finally, from the equilibrium models based in the chemical reactions stoichiometry, although considered very simple, it is possible to get rapid and practical data in relation to evolution of the chemical transformations, such as equilibrium displacement, molar and mass quantities of reactants and products, and to calculate the absorbed and released energy from the establishment of the chemicals reaction balance.

On the other hand, it is necessary to establish the concept of the theoretical model (ideal model) adopted in this study, as well as to represent the global phenomenon of gasification reactions regarding this study. With this purpose, in this study is defined as a theoretical model of chemical reaction that one based on the theory that explains the mass conservation principle in a reagent system. The theoretical term concerns the mass conservation in a reagent system where as the ideal term concerns the formation of new species via a chemical route, along with an ideal or complete conversion of reactants to products.
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