Available online at www.sciencedirect.com
SCIENCE DIRECT®
Energy Conversion and Management 47 (2006) 817–843
ENERGY CONVERSION & MANAGEMENT
www.elsevier.com/locate/enconman

Exergy cost analysis of a coal fired power plant based on structural theory of thermoeconomics

Chao Zhang [a], Yan Wang [a], Chuguang Zheng [a,*], Xinsheng Lou [b]

[a] State Key Laboratory of Coal Combustion, Huazhong University of Science and Technology, Wuhan 430074, PR China
[b] ALSTOM Power Plant Laboratories, Windsor, CT 06095, USA

Received 30 December 2004; accepted 29 June 2005
Available online 10 August 2005

Abstract

In this paper, a cost analysis method based on thermoeconomics is applied to a 300 MW pulverized coal fired power plant located in Yiyang (Hunan Province, China). This method, as derived from the second law of thermodynamics, can provide detailed analysis for cost formation of the power plant as well as the effects of different operating conditions and parameters on the performance of each individual component.

To perform the thermoeconomic analysis of the plant, a simulator is developed from thermodynamic modeling of the plant. With the thermodynamic properties of the most significant mass and energy flow streams being obtained from the plant, this simulator can reproduce the cycle behavior for different operating conditions with relative errors less than 2%. The models of the simulator are refined using data from designed performance tests in this plant.

After simulation, an exergy analysis is performed to calculate the exergy and negentropy of the flows. Then, a thermoeconomic model of the plant is defined based on the functionality of each component using the fuel–product definition. The distribution of the resources throughout the plant and the costs of all flows in the production structure can be calculated by solving a set of equations including the thermoeconomic model of the plant. Three thermoeconomic variables are defined for improving the exergy cost equations in the structural theory of thermoeconomics. Several simulation cases have been analyzed in detail using the improved exergy cost method. The results show that the specific irreversibility cost is more suitable than the unit exergy cost of product in quantifying and representing the production performance of a component. The results provide insights useful to designers and managers of the plant into the relations between the

* Corresponding author. Tel.: +86 027 87542417; fax: +86 027 87545526.
E-mail address: cgzheng@hust.edu.cn (C. Zheng).

0196-8904/$ - see front matter
doi:10.1016/j.enconman.2005.06.014

thermodynamic losses and exergetic costs. This work demonstrates the merits of this advanced thermoeconomic analysis over those conventional analysis techniques based on the first and second laws of thermodynamics.

Keywords: Thermoeconomic analysis; Exergy; Exergy cost; Negentropy; Coal fired power plant

1. Introduction

The development of analysis techniques based on the second law of thermodynamics allows us to allocate and quantify irreversibilities in the production process and to identify which parts of the system and for what reasons they affect the overall inefficiency [1–9]. However, the information provided by these techniques has proved to be insufficient. The following three additional factors must be considered when attempting to achieve effective energy savings in a system with these techniques:

(1) Not every irreversibility can be avoided [4,10]. In reality, the level of exergy savings is limited by the availability of materials and manufacturing methods and the investment cost in an installation. Therefore, the technical possibilities for exergy savings are always lower than the theoretical limit of thermodynamic exergy savings [11,12].
(2) No equivalence exists among the irreversibility of the units of an installation (i.e. the principle of technical non-equivalence of the local irreversibilities) [11]. For example, the same increase/decrease in local irreversibility of a boiler and a generator will lead to different fuel consumptions. Therefore, what matters is not the quantity of the irreversibility but its cost, which is the amount of resources used in order to obtain a product.
(3) Conventional analysis techniques can quantify the additional fuel consumption in an installation, but they cannot identify the real causes of the additional resources consumption [13]. In general, a unit of an installation is not isolated due to its inherent interactions with other units. To find the real causes of economic losses, such relationships should be quantified for further detailed analysis.

Thus, additional constraints and information should be added to the conventional thermodynamic analysis techniques to deal with these issues. An economic analysis should be suitable for this problem of assessing the cost of flows and processes from a global point of view. On the other hand, thermodynamic analysis, which calculates the efficiencies of the units, only quantifies the irreversibilities from a local point of view. However, a new analysis technique, namely thermoeconomics or exergoeconomics, can combine economic and thermodynamic analysis by applying the concept of cost to exergy.

With the development of thermoeconomics, many analysts have proposed different methods based on the second law. These methods can generally be subdivided into two categories: (1) those methods based on cost accounting (e.g. exergetic cost theory [11,14], average cost approach [15], specific cost exergy costing method [16]) and (2) those based on optimization techniques (e.g. thermoeconomic functional analysis [17,18], engineering functional analysis [19]). Cost accounting