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Exergoeconomic Analysis of Internal Combustion Engine Cogeneration System

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Abstract
Exergoeconomic (or thermoeconomic) analysis methodologies combine economic and thermodynamic analysis by applying the cost concept to exergy. This article deals with the exergoeconomic analysis of internal combustion engine based combined heat and power (CHP) system. Energy and exergy balances are applied to each system component. Also cost balances and auxiliary equations are applied to subsystems in the plant, hence, cost formation in the plant is observed. The exergoeconomic analysis is based on specific exergy costing (SPECO) approach. The system under survey in this work is a diesel engine cogeneration system that produces 250 [KW] of electricity and increases the temperature of water from 80 [$^{\circ}$C] to 120 [$^{\circ}$C] at 2 [bar] and 1.75 [kg/s]. This system is very suitable choice to provide required work and heat for residential blocks, large markets and *etc*. The analysis shows that for present design configuration, more attention should be paid to the heat exchanger and diesel engine, from exergoeconomic viewpoint.

Keywords: exergy, exergoeconomic, cost, cogeneration

Introduction

Developing techniques for designing efficient and cost-effective energy systems is one of the foremost challenges that energy engineers face. In a world with finite natural resources and increasing energy demand by developing countries, it becomes increasingly important to understand the mechanisms which degrade energy and resources and to develop systematic approaches for improving the design of energy systems and reducing the impact on the environment [1].

Cogeneration systems have emerged as an effective method of heat conversion due to involving both production of electricity and useful thermal energy in one operation. These systems utilize the waste heat produced during electricity generation and allow more efficient fuel consumption. Thus, this system has more economical benefits than production of these two energy forms in separate systems [2]. Since combined heat and power systems involve the production of both thermal energy, generally in the form of steam or hot water, and electricity, the efficiency of energy production can be increased from current levels that vary from 35% to 55% in the conventional power plants to over 80% in the CHP systems [3].

Combining the second law of thermodynamics with economics (exergoeconomics) using energy or available energy (exergy) for cost purposes provides a powerful tool for systematic study and optimization of complex energy systems. Its goal is to mathematically combine the first or second law of thermodynamic analysis with the economic factors [4]. In the literature, there exist a number of papers concerning exergoeconomic analysis of cogeneration systems. For example, Tsatsaronis and Pisa [5] implemented exergoeconomic principles to the CGAM problem. Hamed *et al.* [4] presented thermoeconomic analysis of a power/water cogeneration plant. Also Baghernejad and Yaghoubi [6] presented exergoeconomic analysis and optimization of an Integrated Solar Combined Cycle System (ISCCS) using genetic algorithm.

Power plants and cogeneration systems powered with internal combustion engines are not a new concept, but there have been no many studies on diesel engine actuated ones in literature. Based on the conditions of energy resources of some Asian and South European countries and fuel to power price structure, diesel engine based power plants and cogeneration have been chosen as the best power producing scheme for some local applications [7]. Therefore more attention should be paid to the analysis of these systems.

In the present work, the exergoeconomic analysis is performed to the diesel engine cogeneration system that introduced by Aceves *et al* [8] and detailed formulations of exergoeconomic parameters are developed to the plant components. So cost formation process in the cogeneration plant is discovered. The cogeneration system that studied in this work is very suitable choice to provide required work and heat for residential blocks, large markets and *etc*.

System description and assumptions made

"Figure 1" shows a schematic diagram of the system. The diesel engine intake air is first compressed to 3 [bar] absolute. Diesel engines are not limited by knock, and it is possible to feed these hot gases to the engine without intercooling, thereby improving the heating efficiency of the system. This improved heating efficiency is obtained at the expense of some loss of specific power due to the reduced density of the hot air, but this is considered a good trade-off for cogeneration applications. Engine operates at compression ratio (15:1) and equivalence ratio of engine is 0.7. Also the