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A Parametric Study on Exergy and Exergoeconomic Assessment of a Diesel Engine Based CHP System

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Abstract
This paper presents exergy and exergoeconomic analysis and parametric study of a Diesel engine based Combined Heat and Power (CHP) system that produces 277 kW of electricity and 282 kW of heat. For this purpose, the CHP system is first thermodynamically analyzed through energy and exergy. Then cost balances and auxiliary equations are applied to subsystems. Finally a parametric study is used to show effects of change in compressor pressure ratio and turbine inlet temperature on important exergy and exergoeconomic parameters of the CHP system in different environment temperatures. The results show that increasing compressor pressure ratio leads to increase in the work output, heating power, exergetic efficiency, exergy destruction cost and exergoeconomic factor of the CHP system in all environment temperatures. Also increasing turbine inlet temperature decreases the work output, exergetic efficiency and exergoeconomic factor and increases the heating power and exergy destruction cost in all environment temperatures.

Keywords: Energy, exergy, exergoeconomics, Diesel engine, CHP

Introduction
Increasing concern regarding the depletion of fossil energy resources and the pollution of the environment has justified the interest in developing high efficiency energy generation techniques. One of the more dependable methods for increasing energy generation efficiency is utilizing every useful power and thermal energy that can be extracted from a fuel source. Combined Heat and Power (CHP) systems are considered the best option to produce both heat and power simultaneously from a single source of fuel [1]. Since CHP systems involve the production of both thermal energy and electricity, the efficiency of energy production can be increased from current levels that vary from 35% to 55% in the conventional plants to over 80% in the combined heat and power systems [2].

The second law of thermodynamics combined with economics represents a very powerful tool for the systematic study and optimization of energy systems. This combination forms the basis of the relatively new field of thermoeconomics or exergoeconomics. Exergoeconomics combines the exergy analysis with the economic principles and incorporates the associated costs of the thermodynamic inefficiencies in the total product cost of an energy system. These costs can conduct designers to understand the cost formation process in an energy system and it can be utilized in optimization of thermodynamic systems, in which the task is usually focused on minimizing the unit cost of the system product [3].

In the literature, there exist a number of papers concerning exergetic and exergoeconomic analysis of CHP systems. Sahoo presented exergoeconomic analysis and optimization of a cogeneration system using evolutionary programming [4]. Baghernejad and Yaghoubi carried out exergoeconomic analysis and optimization of an Integrated Solar Combined Cycle System (ISCCS) using genetic algorithm [5]. Also Mohammadkhani et al. performed exergy and exergoeconomic analysis and optimization of a Diesel engine based CHP system [6].

Power plants and CHP systems based on internal combustion engines are not a new idea but there have been no many studies on Diesel engine based ones in literature. Diesel engine based CHP and plants are the best power production option for some applications in some Asian and South European countries [6].

In the present work, exergy and exergoeconomic analysis are performed to the Diesel engine based CHP system that is considered by Aceves et al. [7] for combined power and heating applications. Also a parametric study is used to show effects of change in compressor pressure ratio and turbine inlet temperature on important exergy and exergoeconomic parameters of the system for four environment temperatures in Tehran, the capital city of Iran: spring temperature (21 ˚C), summer temperature (29 ˚C), autumn temperature (14 ˚C) and winter temperature (6 ˚C).

System description and assumptions made
A schematic diagram of the CHP system is shown in "Figure 1". The system main equipment consists of compressor, Diesel engine, turbine and heat exchanger. Engine operates at compression ratio (15:1) and equivalence ratio of the engine is 0.7. Also fuel heating power into the engine is 600 kW and the fuel used in the engine is Diesel fuel. The engine exhaust gases flow through the turbine of the turbocharger unit to generate needed shaft work for the compressor. The cooling water loop goes from the engine to a heat exchanger being heated by exhaust gases. Process heat generated in the CHP system is recovered from this hot water and then the water is circulated into the engine [7].