Parametric Evaluation of Gas Turbine System with Exergy Method

Nishant Modi, Parth Mody

1, 2 School of Technology, Pandit Deendayal Petroleum University, Gujarat, India.

Abstract
This paper represents the parametric evaluation of 25 MW gas turbine power system which consumes Ethane. The thermodynamic model for the examined system has been simulated in Engineering Equation Solver (EES) software based on energetic and exergetic perspectives. The various performance parameters such as energetic efficiency and exergetic efficiency are determined. Moreover, the effect of environmental temperature on the exergy destruction rate for compressor, combustion chamber, and gas turbine have been evaluated. The combustion chamber is identified as the highest destructive component with 79.447 MW of exergy destruction. Parametric study demonstrates that one degree rise in environmental condition results in 30 kW of exergy destruction in compressor.
Keywords: Exergy Analysis, Gas Turbine Power System, Turbine Inlet Temperature.

Nomenclature

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>Energy, kJ</td>
</tr>
<tr>
<td>T</td>
<td>Temperature, °C</td>
</tr>
<tr>
<td>˙x</td>
<td>Exergy rate, kW</td>
</tr>
</tbody>
</table>

Subscripts
in     Inlet
out    Outlet
g      Combustion gases
a      Air
f      Fuel
D      Destruction

Abbreviations
TIT    Turbine Inlet Temperature
C.C   Combustion chamber
E.G   Electric generator

1. Introduction

Increased global energy demand and inefficiency of existing system components lead the thermal engineers to re-examine systems to reduce energy devastation. For that first law of thermodynamic principles are used which is generally based on overall energy efficiency of system and does not provide any information about energy loss. Huang [1] concluded that first law consideration is not enough for realistic measure of system inefficiency. To overcome the demerits of energy analysis, the second law based analysis is developed, called exergetic analysis [2]. Exergy analysis counts the qualitative measure of energy loss. Also, it's provides the location, where the exergy destruction takes place.

Mohamad Javad Ebadi and Mofid Gorji-Bandpy [3] have applied the exergy method to investigate the effect of turbine inlet temperature (TIT) on the performance of gas turbine plant and confirmed that TIT is the crucial parameter. From last decades many attempts were made to optimize gas turbine power systems for the efficient utilization of energy [4]. Therefore, the aim of present study is to analyze the thermodynamic performance of gas turbine system components with the deviation in environmental conditions. In this present work, parametric evaluation have been carried out for gas turbine power system operates on Ethane as a fuel.

2. System Description

The schematic diagram of examined system is illustrated in Fig. 1. The gas turbine power system mainly consists of compressor, combustion chamber, and the turbine. Fresh air is sucked in the compressor (state-1) and got compressed isentropically (state-2), then the fuel is fired (state-3) and combustion takes place at constant pressure. After combustion, product gases will enter (state-4) in the turbine where get expand (state-5) and produce electrical power.
3. Thermodynamic Modelling

This section consists of sets of equations which describe the thermodynamic model for the examined system.

First law analysis:

\[ E_{in} = E_{out} \]  

(1)

\[ \dot{m}_g = \dot{m}_a + \dot{m}_f \]  

(2)

Second law analysis:

\[ \dot{\gamma}_{x,\text{in}} = \dot{\gamma}_{x,\text{out}} + \dot{\gamma}_{x,\text{loss}} + \dot{\gamma}_{x,D} \]  

(3)

4. Methodology and Validation

Thermodynamic model is developed in the engineering equation solver (EES) software [4]. Also, the model is validated by comparing the results obtained from the presented model with the results obtained by [5]. Very minor deviation in the results indicates that the developed model is acceptable.

5. Results and Discussion

The exergy destruction rate in various components is illustrated in Table 1. It is observed that the combustion chamber has the highest value of exergy destruction followed by gas turbine and compressor. The reason behind this is chemical reaction causes higher entropy generation within a system component.

Table 1. Exergy destruction in various components

<table>
<thead>
<tr>
<th>Component</th>
<th>Exergy destruction rate (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>2233</td>
</tr>
<tr>
<td>Combustion chamber</td>
<td>79447</td>
</tr>
</tbody>
</table>

6. Conclusion

The energetic and exergetic analysis of the gas turbine power system has been carried out in the present study. It has been concluded that the combustion chamber has the highest value of energy devastation close to 79.447 MW followed by gas turbine and compressor. Also, it is noteworthy that exergetic efficiency is lower than energetic efficiency for all above mentioned components, which indicates that the exergetic analysis is the more realistic approach than the energetic analysis. Moreover, it is noteworthy that the higher exergy destructions took place at higher ambient condition. Also, Parametric study demonstrates that one degree rise in environment condition resulted in 30 kW of exergy destruction in compressor.

Acknowledgments

Authors are very grateful to the Department of Mechanical Engineering, Pandit Deendayal Petroleum University for providing such kind of opportunity.

References


