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Thermodynamic Modelling and Gas Turbine Exergy Analysis

R Vinod[1] and M Rakesh[2]
Department of Mechanical Engineering, QIS Engineering College, Ongole
[1]Corresponding Author: vinodrammech@gmail.com

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Abstract: *The assessment and detection of where a gas turbine system is inefficient are done by performing a thorough thermodynamic model and exergy analysis. With the support of the first and second laws of thermodynamics, the model is able to estimate energy and exergy through the compressor, combustor and turbine. This study points out that the main location of exergy loss is the area of combustion due to big temperature drops and unavoidable irreversibility. It is important to use exergy and thermal efficiency as major measures for evaluating performance. Research outcomes support maintaining and improving the productivity of gas turbine systems by suggesting better new ways of doing things.*

Keywords: *Ambient temperature, Combined cycle power plant Compression ratio Efficiency Exergy TIT*

I. Introduction

The reason gas turbines are vital in modern power production and propulsion is their solid high power-to-weight ratio, high dependability and flexible choice of fuel. Even so, optimizing how they function and their efficiency is not easy, mainly when energy is getting more costly and people are worried about the environment. Understanding how energy changes in gas turbines mainly relies on thermodynamic modelling. Engineers and academics rely on it to review part performance, design various system conditions and predict how the system might change if its arrangement is altered.

Exergy analysis adds new insights by focusing on quality and noticing where parts of the system cannot be reversed. The first law of thermodynamics takes care of energy conservation, while energy degradation and losses are explained by the second law using exergy. Analysis of exergy commonly points out the main problems in gas turbine operations such as those in the combustion chamber and the exhaust.

This study attempts to analyze how a gas turbine system performs by merging thermodynamic modeling and exergy analysis. Working to find the key reasons for energy loss and recommending how to address them is the main aim. This analysis supports making gas turbines for power production and aviation more sustainable and efficient.

II. Gas Turbine

A gas turbine is an internal combustion engine that uses a fast-rotating shaft to change the energy from fuel into mechanical energy. It has three main pieces—a compressor, a combustor and a turbine—and is operated on the Brayton cycle. Gas expands throughout the turbine after being compressed, mixed with fuel and burnt in the combustor which turns the crankshaft. That gas turbines are very efficient, compact and able to burn several fuels, including natural gas, diesel and biofuels, is why they are widely seen in power plants, aeroplane engines and industry. The first law of thermodynamics serves as the foundation for energy analysis, which is essential to thermodynamic modelling of gas turbine systems. Each component—the compressor, combustor, and turbine—has its energy input, output, and losses assessed. Energy is seen as a conserved quantity in this study, which means that it can only be changed rather than created. Fuel's chemical energy is transferred into thermal energy by combustion in gas turbines, which the turbine then partially transforms into mechanical energy for practical tasks like propulsion or electricity generation.

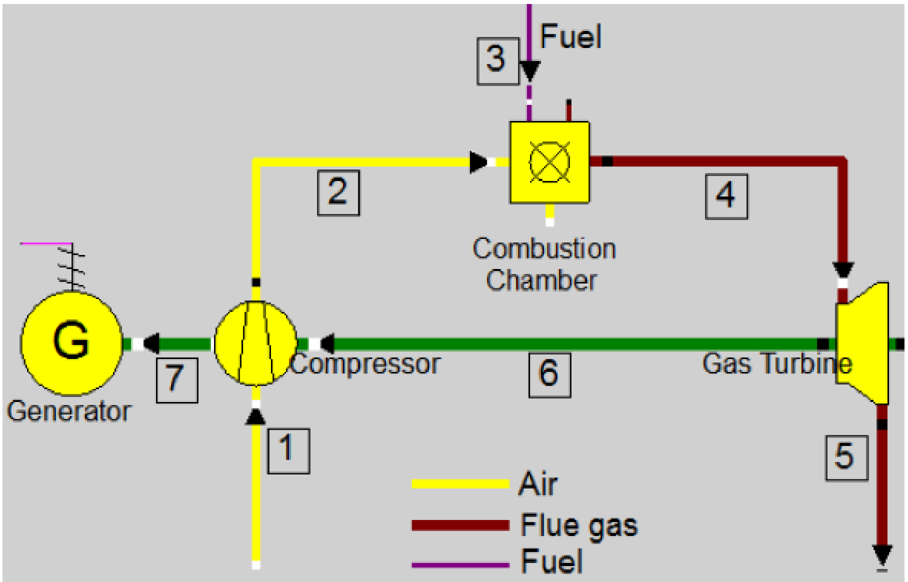

Fig 1: Gas turbine cycle

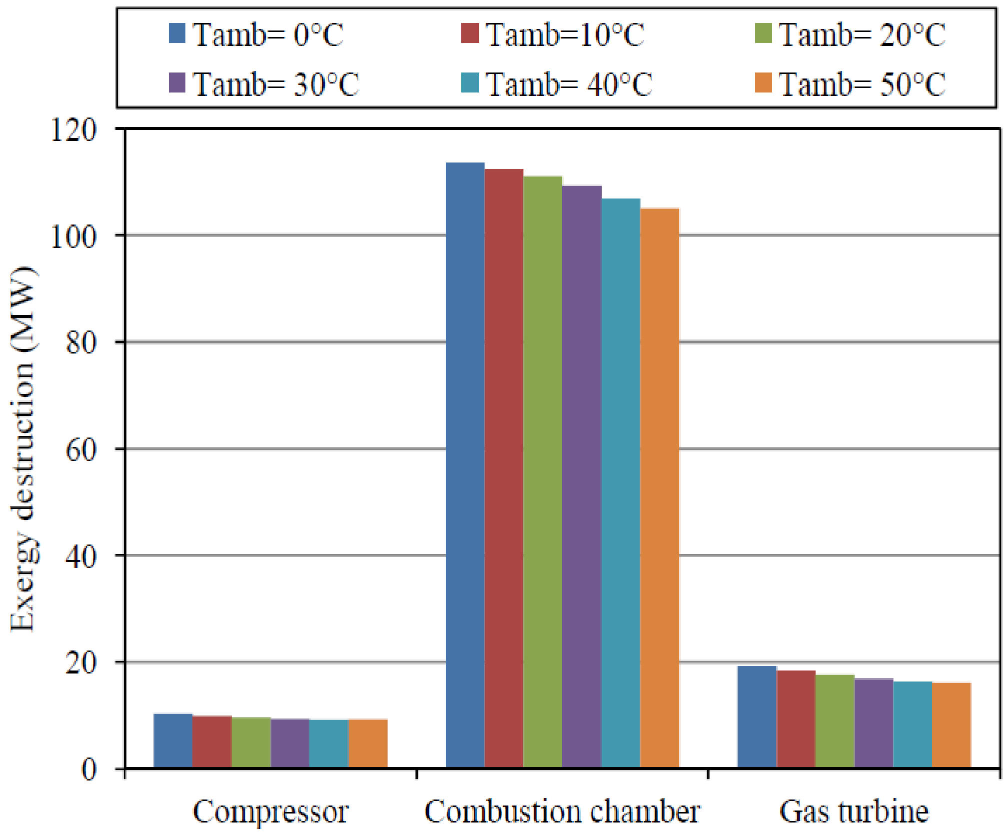

Fig 2: Variation of exergy destruction rate for 100% load

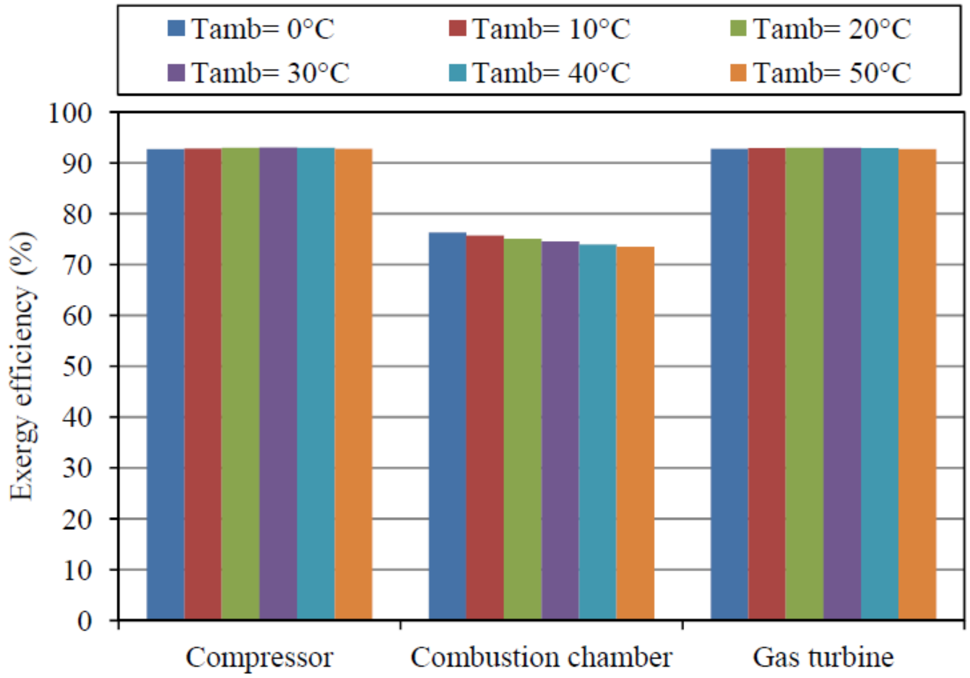

Fig 3: Variation of exergy destruction rate for GT load 100%

While the combustor provides heat energy through fuel combustion, the compressor uses a portion of the turbine's output to compress incoming air. The hot gases are subsequently expanded by the turbine to produce work. Energy analysis provides a fundamental understanding of system performance by assisting in the calculation of metrics such as heat rate, specific fuel consumption, and thermal efficiency.

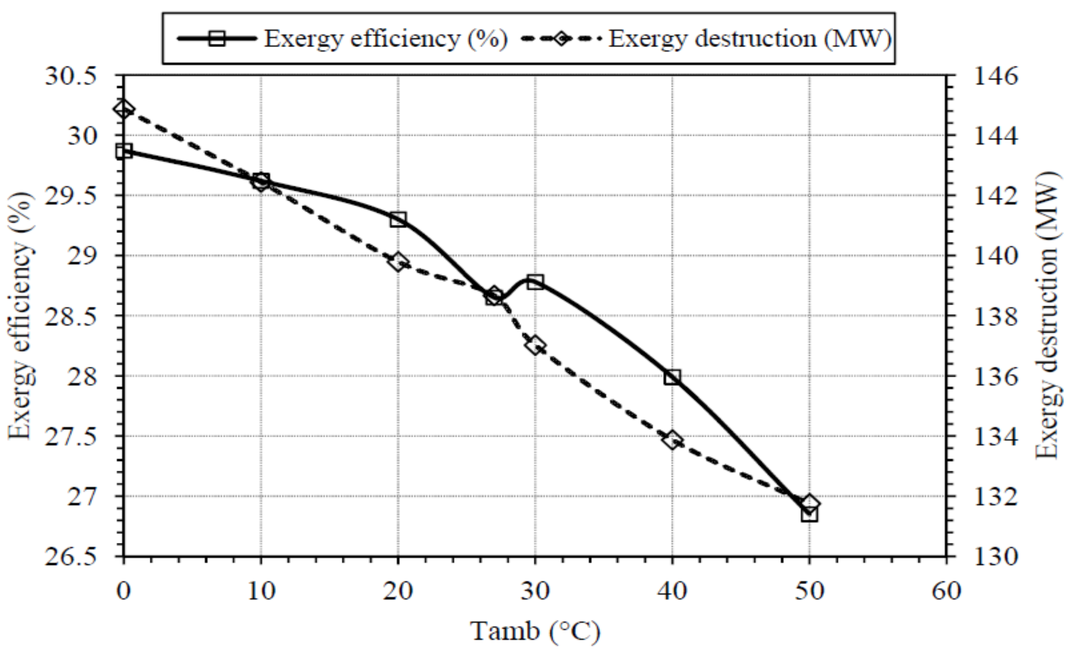

Fig 4: : Variation of exergy for gas turbine

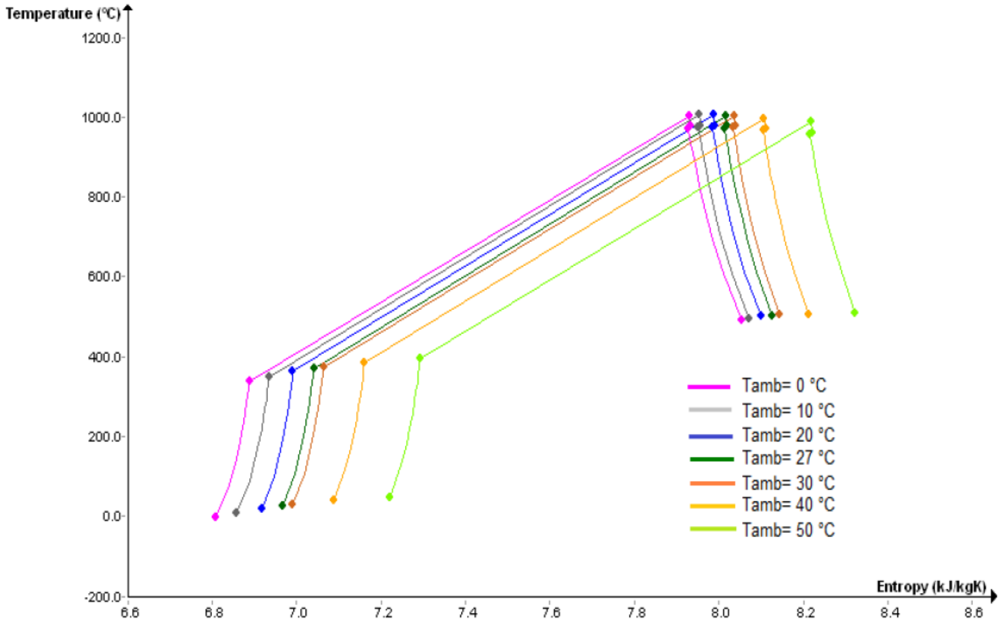

Fig 5: T-S Gas turbine

However, the quality and utility of energy are not taken into consideration by energy analysis alone. It treats all types of energy equally, regardless of their capacity for labor. Although it shows how much energy is used or lost, it doesn't explain why. For a more thorough understanding of gas turbine inefficiencies and optimization possibilities, exergy analysis is required.

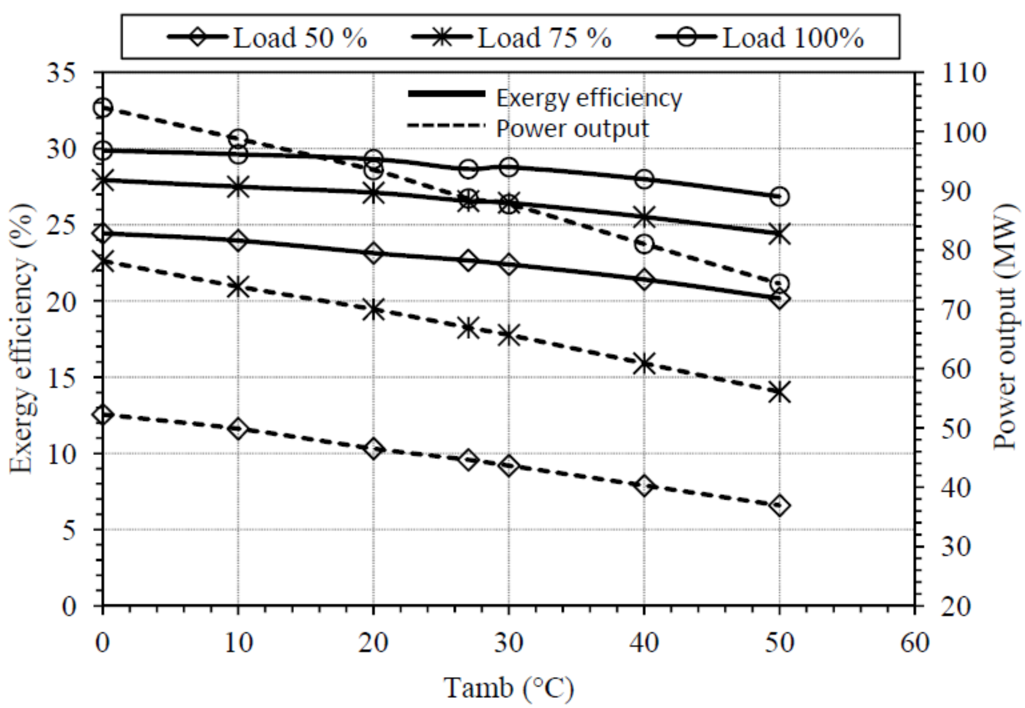

Fig 6: Variation of gas cycle with respect to temperature

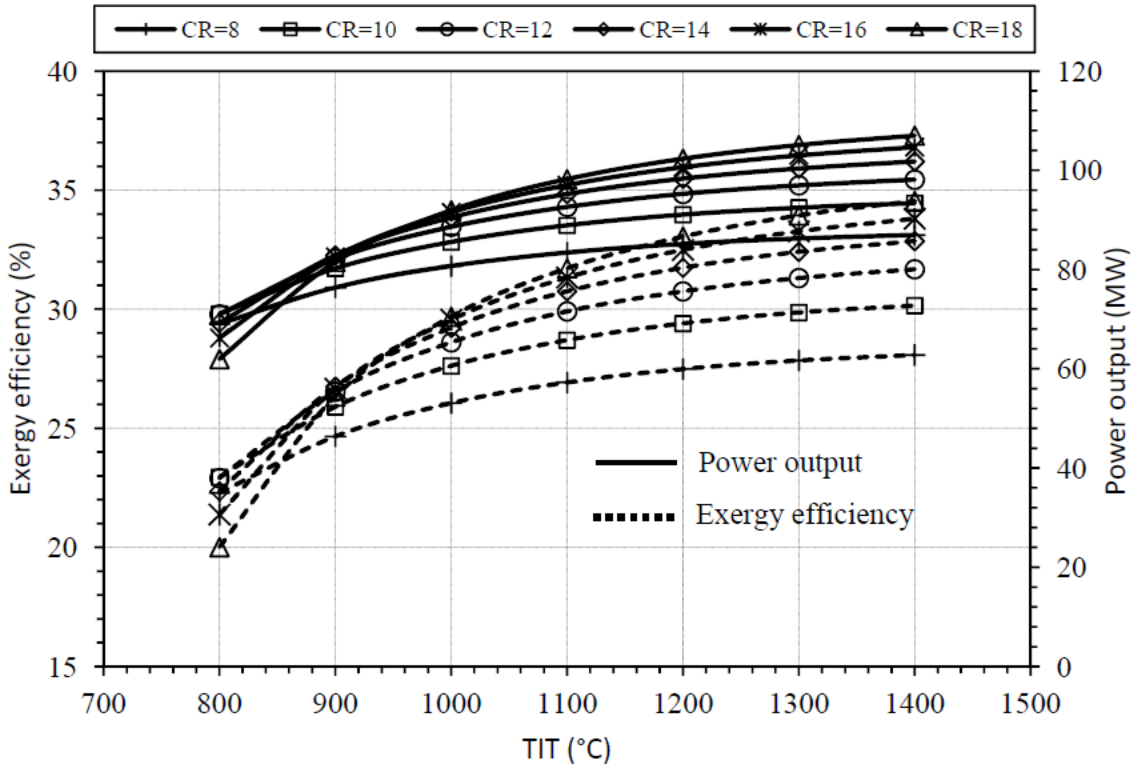

Fig 7: Effect of TIT for gas turbine

III. Conclusion

Using both thermodynamic modeling and exergy analysis helps improve the performance of gas turbine systems. Though energy analysis talks about the overall performance of the plant, exergy analysis allows engineers to track down where the losses occur and how great they are. This study underlines that most exergy is lost in the combustion chamber, so improvements in both combustion technology and thermal control are needed. If engineers use such tools, the design, operation and overall sustainability of gas turbines are improved, allowing for better and more eco-friendly production of energy in both power plants and on vehicles.

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