Introductory Chapter

Overview

Konstantin Volkov
School of Mechanical and Automotive Engineering,
Faculty of Science, Engineering and Computing, Kingston University, London
UK

1. Introduction

Gas turbines are a vital and active area of research because they play a dominant role in the fields of power, propulsion and energy. They are used from the simple cycle machines employed to compress gas, pump oil and provide power, to the combined heat and power gas turbines used to provide electrical power, heating and cooling for industrial plants. Gas turbines are widely used in power plants and mechanical drive applications and, as these plants can be configured in a number of ways, the gas turbine manufacturer needs to balance the requirements of each user to optimize the design.

The conceptual design process of gas turbines is complex, involving multiple engineering disciplines. Aerodynamics, thermodynamics, heat transfer, materials science, component design, and structural analysis are a few of the fields employed when down selecting an appropriate gas turbine configuration. Because of the complexity involved, it is critical to have a process that narrows gas turbine options without missing the optimum.

The robustness of a design process is dependent on a number of factors including clear requirements and objectives, capture of the design parameters, knowledge capture and dissemination, validated procedures, repeatability, manufacturability, and the capability to consider the widest possible scope in the search for a conceptual design solution. The use of a constraint modelling technique has provided a framework where the various elements and tools involved in a design process can be integrated through various communication methods.

The design parameters of the gas turbines need to be chosen carefully to balance their influence on the reliability, maintainability, cost, efficiency and emissions of a gas turbine based power plant. Efficiency and reliability are two major parameters that should both be considered at the beginning of a new design project. To get higher efficiency means higher firing temperatures, higher pressure ratios, exotic materials, complicated cooling systems, all factors which jeopardize the cost and the reliability of the product. The aim of the product design team is to reach the optimum balance for these parameters, and for the demands and specifications of the individual customer. The gas turbine design process is not completely linear since the design steps are highly interdependent. A number of iterations are usually necessary in selecting a final configuration.

This book focuses on development and improvement of methods and techniques of analysis and diagnostics of efficiency, operation and maintenance of gas turbines. Authors from several countries have contributed chapters dealing with a wide range of issues related to analysis of gas turbines and their engineering applications. Gas turbine engine defect diagnostic and condition monitoring systems, operating conditions of open gas turbines, reduction of jet mixing noise, recovery of exhaust heat from gas turbines, appropriate materials and coatings, ultra micro gas turbines and applications of gas turbines are discussed. Analytical and experimental methods employed to identify failures and quantify operating conditions and efficiency of gas turbines that are encountered in engineering applications.

The book contains 11 chapters written by the specialists from various countries who are working in field of design, optimization, maintenance and diagnostics of gas turbines.

2. Ultra-micro-gas-turbines

Ultra-micro gas turbine generator, that is a power device with high power density, is analysed in this chapter. This generator, although the covered power range oscillates between 100 and 500 W, is characterized by reduced overall dimensions. Design issues and realization of the mechanical components is considered. The economic impact of these devices depends on the performance levels and the manufacturing costs, both of which have yet to be proven. Competitiveness of ultra-micro gas turbine generator with conventional machines in a cost per installed kilowatt is discussed.

3. The selection of materials for marine gas turbine engines

This chapter presents hot corrosion results of selected nickel based superalloys for marine gas turbine engines both at high and low temperatures. The results are compared with a new alloy under similar conditions in order to understand the characteristics of the selected superalloys. It is observed that the nature and concentration of alloying elements mainly decide the resistance to type I and type II hot corrosion. Relevant reaction mechanisms that are responsible for degradation of various superalloys under marine environmental conditions are discussed. The necessity to apply smart coatings for their protection under high temperature conditions is stressed for the enhanced efficiency as the marine gas turbine engines experience type I and type II hot corrosion during service. Hot corrosion problems experienced by titanium alloy components under marine environmental conditions are explained along with relevant degradation mechanisms and recommended a developed smart coating for their effective protection.

Two chapters were written by the same authors and focus on energy and exergy analysis of the Brayton cycle and operation of gas turbines in hot humid and arid climates.

4. Energy, exergy and thermoeconomics analysis of water chiller cooler for gas turbines intake air cooling

Gas turbine power plants operating in arid climates are considered in this chapter. They suffer a decrease in output power during the hot summer months because of the high specific volume of air drawn by the compressor. Energy and exergy analysis of a Brayton cycle coupled to a refrigeration air cooling unit is discussed and shows a promise for increasing the output power with a little decrease in thermal efficiency. A thermo-economics algorithm is developed to estimate the economic feasibility of the cooling system. The cost of adding the air cooling system is also investigated and a cost function is derived that incorporates time-dependent meteorological data, operation characteristics of the gas turbine and the air intake cooling system and other relevant parameters such as interest rate, lifetime, and operation and maintenance costs.

5. Energy and exergy analysis of reverse Brayton refrigerator for gas turbine power boosting

The use of reverse Brayton cycle to boost up the power of gas turbine power plants operating in hot humid ambiance is discussed in this chapter. The effects of irreversibilities in the system components (air compressor, combustion chamber, turbine, air cooler, expander and the mixing chamber) are evaluated along with the exergetic power gain ratio and the exergetic thermal efficiency change of the cycle. The dependency of the power gain, thermal efficiency and exergetic efficiency on the operation parameters are presented and analyzed.

6. Gas turbines in unconventional applications

Unconventional gas turbine applications are discussed in this chapter. Some of engineering solutions are intended for smaller gas turbine systems, where the regenerative heat exchanger supplies energy for an additional thermal cycle. Coupling of Brayton cycle with several other thermodynamic cycles (e.g. another Brayton, Diesel or Stirling cycles) is discussed, and advantages of hybrid systems are analyzed. Large international development programmes are reviewed, and several hydrogen-fuelled gas turbine concepts are proposed. Potential combination of a hydrogen-fuelled gas turbine and a nuclear power generation unit which is used to cover peak load power demands in a power system is described.

7. The recovery of exhaust heat from gas turbines

In this chapter different techniques for recovering the exhaust heat from gas turbines are discussed, evaluating the influence of the main operating parameters on plant performance. A unified approach for the analysis of different exhaust heat recovery techniques is proposed. The methodology is based on relationships of general validity and characteristic plane for exhaust heat recovery, that indicates directly the performance obtainable with different recovery techniques, compared to a baseline non-recovery plant. An innovative scheme for external heat recovery is presented. It envisages repowering existing combined cycle power plants through injection of steam produced by an additional unit consisting of a gas turbine and a heat recovery steam generator.

8. Gas turbine diagnostics

This chapter focuses on reliability of gas path diagnosis. New solutions are proposed to reduce the gap between simulated diagnostic process and real engine maintenance conditions. Thermodynamic models, data validation and tracking the deviations, fault classification, fault recognition techniques, multi-point diagnosis, diagnosis under transient conditions, and system identification techniques are presented. Practical recommendations are given to develop an effective condition monitoring system.

9. Models for training on a gas turbine power plant

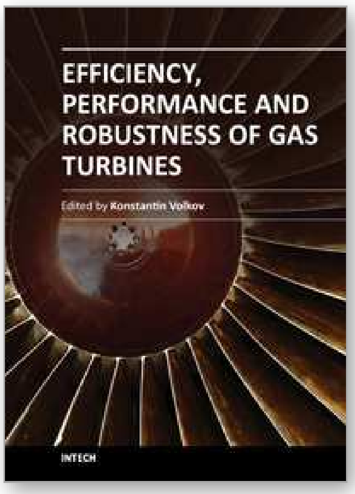
In this chapter a summary of the gas turbine simulator development and its model characteristics are described. Stochastic and discrete events models are not considered, but deterministic models of industrial processes are contemplated. The simulator was tested in all the operation range from cold start to 100% of load and fulfils the performance specified by the client, including a comparison of its results with plant data.

10. Summary

Many different methods exist to integrate various design elements into an overall process. Ideally, designers like to perform all design steps concurrently in order to minimize the overall time required to conduct a study. Whole books have been written to address each of steps involved in design of gas turbines, so this book cannot possible cover all issues. Hopefully, it has at least introduced the reader to tools that are currently available.

The book covers many aspects of gas turbine design and operation. The book represents the latest research of various groups of internationally recognized experts in gas turbine studies. This book is intended for engineers and technical workers in design, optimisation and maintenance of gas turbines, and specialists is thermodynamics and heat transfer, particularly those involved with energy systems and transportation systems that make use of gas turbines. It will be of interest to academics working in aeroengine control and to industrial practitioners in companies concerned with design of gas turbines. The works presented in the book are easily extendible to be relevant in other area in which gas turbines play a role such as power engineering and marine engineering.

The open exchange of scientific results and ideas will hopefully lead to improved reliability of gas turbines and aeroengines. The book presents necessary data and helpful suggestions to assist scientists and engineers involved in the design, selection and operation of gas turbines.



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