Gas Turbine Combustion

This revised edition provides understanding of the basic physical, chemical, and aerodynamic processes associated with gas turbine combustion and their relevance and application to combustor performance and design. Also introduced are many new concepts for ultra-low emissions combustors, and new advances in fuel preparation and liner wall-cooling techniques for their success. It details advanced and practical approaches to combustor design for the clean burning of alternative liquid fuels derived form oil shades, tar sands, and coal.
There is an increasing industry interest in integrated gas turbine combined cycle plants in which coal gasifiers provide the fuel for the gas turbines. Some gasifier plant designs, including the air-blown processes, some integrated oxygen blown processes and some oxygen-blown processes followed by heavy moisturization, produce fuel gases which have lower heating values ranging from 130 to below 100 BTU/scf for which there is little gas turbine combustion experience. This program has the objectives to: Parametrically determine the effects of moisture, nitrogen and carbon dioxide as diluents so that the combustion characteristics of many varieties of gasification product gases can be reasonably predicted without physically testing each specific gas composition; determine emissions

characteristics including NO[sub x], CO, levels etc. associated with each of the diluents; operate with two syngas compositions; DOE chosen air-blown and integrated oxygen-blown, to confirm that the combustion characteristics are in line with predictions; determine if logical" refinements to the fuel nozzle will yield improved performance for LBTU fuels; determine the conversion rate of ammonia to NO[sub x]; determine the effects of methane inclusion in the fuel.

Filmed work by students of the School of Design, Swinburne University of Technology.

Gas Turbine CombustionAlternative Fuels and Emissions, Third EditionCRC Press

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This book focuses on the development of novel

combustion approaches and burner designs for clean power generation in gas turbines. It shows the reader how to control the release of pollutants to the environment in an effort to reduce global warming. After an introduction to global warming issues and clean power production for gas turbine applications, subsequent chapters address premixed combustion, burner designs for clean power generation, gas turbine performance, and insights on gas turbine operability. Given its scope, the book can be used as a textbook for graduate-level courses on clean combustion, or as a reference book to accompany compact courses for mechanical engineers and young researchers around the world.
Cranfield International Symposium Series, Volume 10: Combustion in Advanced Gas Turbine Systems covers the proceedings of an International Propulsion Symposium, held at the College of Aeronautics in Cranfield in April 1967. The book focuses on the processes, methodologies, reactions, and transformations involved in chemical combustion. The selection first takes a look at the design considerations in advanced gas turbine combustion chambers, combustion in industrial gas turbines, and combustion development on the Rolls-Royce Spey engine. Discussions focus on mechanical condition, carbon-formation and exhaust smoke, system requirements, fuel oil ash deposition and corrosion, combustion-system design,

performance requirements, types of primary zone, fuel injection, and combustion chamber types. The text then examines subsonic flow flameholder studies using a low pressure simulation technique; stabilization of hydrogen diffusion flames by flame-holders in supersonic flow at low stagnation temperatures; and augmentation systems for turbofan engines. The book takes a look at a consideration of the possible use of refractory ceramic materials for advanced combustion chamber design; cooling of flame tubes by steam injection; and combustion problems in the massive steam injection gas turbine. The selection is a valuable source of information for researchers interested in the process of combustion in advanced gas turbine systems.

Reflecting the developments in gas turbine combustion technology that have occurred in the last decade, Gas Turbine Combustion: Alternative Fuels and Emissions, Third Edition provides an up-to-date design manual and research reference on the design, manufacture, and operation of gas turbine combustors in applications ranging from aeronautical to power generation. Essentially self-contained, the book only requires a moderate amount of prior knowledge of physics and chemistry. In response to the fluctuating cost and environmental effects of petroleum fuel, this third edition includes a new chapter on alternative fuels. This chapter presents the physical and chemical properties of conventional (petroleum-based) liquid and gaseous fuels for gas turbines; reviews the properties of alternative (synthetic) fuels and conventional-alternative fuel blends; and describes the influence of these different fuels and their blends on combustor performance, design, and emissions. It also discusses the special requirements of aircraft fuels and the problems encountered with fuels for industrial gas turbines. In the updated chapter on emissions, the authors highlight the quest for higher fuel efficiency and reducing carbon dioxide emissions as well as the regulations involved. Continuing to offer detailed coverage of multifuel capabilities, flame flashback, high off-design combustion efficiency, and liner failure studies, this best-selling book is the premier guide to gas turbine combustion technology. This edition retains the style that made its predecessors so popular while updating the material to reflect the technology of the twenty-first century.

Oxides of nitrogen (NO[subscript x]), carbon monoxide (CO) and other combustion by-products of gas turbines have long been identified as harmful atmospheric pollutants to the environment and humans. Various government agencies place restrictions on emissions and often require some sort of emissions monitoring even for new low emission gas turbines. Predicting actual emissions from operating parameters that affect the formation of pollutants, called parametric emissions monitoring system (PEMS), has potential economic advantages compared to a continuous emissions monitoring system (CEMS). The problem is that a simple applicable PEMS does not exist. During this study, a gas turbine combustor model applying first engineering principles was developed to predict the emission formation of NO[subscript x]and CO in a gas turbine. The model is based on a lean-premixed combustor with a main and pilot burner including the function of a bleeding air valve. The model relies on ambient condition and load. The load is expressed as a percentage of the target speed of the gas producer turbine. Air flow and fuel flow for the main and pilot burner are calculated by the model based on the load through a set of measured input data for a specific gas turbine. To find the combustion temperature characteristics, the combustor is divided into several zones. The temperature for each zone is calculated by applying an energy balance. To predict NO[subscript x] and CO, several correlations explored by various researchers are used and compared against each other, using the calculated temperatures, pressures and equivalence ratios. A comparison between collected emissions examples from a turbine test cell data spreadsheet and predicted emissions by the developed model under the same conditions show a highly accurate match for NO[subscript x] emission at any load. Because of the high variation of CO at part load, the model predictions only match the CO data set at full load. Historically, the development of new industrial gas turbines has been primarily driven by the intent to achieve higher efficiency, lower operating costs and lower emissions. Higher efficiency and lower cost is obtained through higher turbine operating temperatures, while reduction in emissions is obtained by extending the lean operating limit of the combustor. However reduction in the lean stability limit of operation is limited greatly by the chemistry of the combustion process and by the occurrence of thermo-acoustic instabilities. Solar Turbines, CFD Research Corporation, and Los Alamos National Laboratory have teamed to advance the technology associated with laser-assisted ignition and flame stabilization, to a level where it could be incorporated onto a gas turbine combustor. The system being developed is expected to enhance the lean stability limit of the swirl stabilized combustion process and assist in reducing combustion oscillations. Such a system has the potential to allow operation at the ultra-lean conditions needed to achieve NO(subscript x) emissions below 5 ppm without the need of exhaust treatment or catalytic technologies. The research effort was focused on analytically modeling laser-assisted flame stabilization using advanced CFD techniques, and experimentally demonstrating the technology, using a solid-state laser and low-cost durable optics. A pulsed laser beam was used to generate a plasma pool at strategic locations within the combustor flow field such that the energy from the plasma became an ignition source and helped maintain a flame at ultra lean operating conditions. The periodic plasma generation and decay was used to nullify the fluctuations in the heat release from the flame itself, thus decoupling the heat release from the combustor acoustics and effectively reducing the combustion oscillations. The program was built on an existing technology base and includes: extending LANL's existing laser stabilization experience to a sub-scale combustor rig, performing and validating CFD predictions, and ultimately conducting a full system demonstration in a multi-injector combustion system at Solar Turbines.

Blending fuels with hydrogen offers the potential to reduce NOx and CO2 emissions in gas turbines, but doing so introduces potential new problems such as flashback. Flashback can lead to thermal overload and destruction of hardware in the turbine engine, with potentially expensive consequences. The little research on flashback that is available is fragmented. Flashback Mechanisms in Lean Premixed Gas Turbine Combustion by Ali Cemal Benim will address not only the overall issue of the flashback phenomenon, but also the issue of fragmented and incomplete research. Presents a coherent review of flame flashback (a classic problem in premixed combustion) and its connection with the growing trend of popularity of more-efficient hydrogen-blend fuels Begins with a brief review of

industrial gas turbine combustion technology Covers current environmental and economic motivations for replacing natural gas with hydrogen-blend fuels
The design of gas turbine combustion chambers is becoming increasingly more sophisticated as demands on performance increase and combustor operating conditions become more and more harsh. The design compromises which account for much of the art in successful combustor design have become more difficult as gas turbine cycles reach higher pressure and temperature levels and design objectives become more rigorous. This is particularly true for military applications of gas turbines, for both manned and unmanned aircraft. Concurrently, there is significant pressure for the combustor designer to reduce development time and cost, reduce life cycle costs, increase fuel tolerance and continue to minimize the environmental impact of the combustion process. In the past two decades, an increasing amount of fundamental knowledge of chemical, aerodynamic and thermal phenomena, plus a more detailed understanding of sprays, has been applied with considerable success to practical combustor design. The papers presented at this symposium 'Combustion and Fuels in Gas Turbine Engines' are categorized under the following four subject headings: Alternative Fuels and Fuel Injection, Combustor Development, Soot and Radiation, and Combustion Modeling. Keywords: NATO furnished, After burners, Alternative fuels, Atomization drops, Distribution, Soot.
In spite of the increasing presence of renewable energy sources, fossil fuels will remain the primary supply of the world's energy needs for the upcoming future. Modern gas-turbine based systems represent one of the most efficient large-scale power generation technology currently available. Alongside this, gas-turbine power plants operate with very low emissions, have flexible operational characteristics and are

able to utilize a broad range of fuels. It is expected that gas-turbine based plants will play an important role as an effective means of converting combustion energy in the future as well, because of the vast potential energy savings. The numerical approach to the design of complex systems such as gas-turbines has gained a continuous growth of interest in the last few decades. This because simulations are foreseen to provide a tremendous increase in the combustor efficiency, fuel-flexibility and quality over the next future. In this dissertation, an advanced turbulent combustion technique is implemented and progressively developed for the simulation of all the features that are typically observed in stationary gas-turbine combustion, including hydrogen as a fuel. The developed turbulent combustion model retains most of the accuracy of a detailed simulation while drastically reducing its computational time. As a result of this work, the advancement of power generation plants can be accelerated, paving the way for future developments of alternative fuel usage in a cleaner and more efficient combustion.

There has been a remarkable difference in the research and development regarding gas turbine technology for transportation and power generation. The former remains substantially florid and unaltered with respect to the past as the superiority of air-breathing engines compared to other technologies is by far immense. On the other hand, the world of gas turbines (GTs) for power generation is indeed characterized by completely different scenarios in so far as new challenges are coming up in the latest energy trends, where both a reduction in the use of carbon-based fuels and the raising up of renewables are becoming more and more important factors. While being considered a key technology for base-load operations for many years, modern stationary gas turbines are in fact facing the challenge to balance electricity from variable renewables with that from flexible conventional power plants. The book intends in fact to provide an updated picture as well as a perspective view of some of the abovementioned issues that characterize GT technology in the two different applications: aircraft propulsion and stationary power generation. Therefore, the target audience for it involves design, analyst, materials and maintenance engineers. Also manufacturers, researchers and scientists will benefit from the timely and accurate information provided in this volume. The book is organized into three main sections including 10 chapters overall: (i) Gas Turbine and Component Performance, (ii) Gas Turbine Combustion and (iii) Fault Detection in Systems and Materials.

The development of clean, sustainable energy systems is one of the pre-eminent issues of our time. Most projections indicate that combustion-based energy conversion systems will continue to be the predominant approach for the majority of our energy usage, and gas turbines will continue to be important combustion-based energy conversion devices for many decades to come, used for aircraft propulsion, ground-based power generation, and mechanical-drive applications. This book compiles the key scientific and technological knowledge associated with gas turbine emissions into a single authoritative source. The book has three sections: the first section reviews major issues with gas turbine combustion, including design approaches and constraints, within the context of emissions. The second section addresses fundamental issues associated with pollutant formation, modeling, and prediction. The third section features case studies from manufacturers and technology developers, emphasizing the system-level and practical issues that must be addressed in developing different types of gas turbines that emit pollutants at acceptable levels.

Reflecting the developments in gas turbine combustion technology that have occurred in the last decade, Gas Turbine Combustion, Fourth Edition provides an up-to-date design manual and research reference on the design, manufacture, and operation of gas turbine combustors in applications ranging from aeronautical to power generation. Essentially self-contained, the book only requires a moderate amount of prior knowledge of physics and chemistry. New co-author Dr. Scott Samuelson, worked closely with Arthur Lefebvre, and has retained the readable, easy to follow approach of the original editions while updating the coverage of design, combustor performance, fuels, emissions, and other topics.

In recent years domestic natural gas has experienced a considerable growth in demand particularly in the power generation industry. However, the desire for energy security, lower fuel costs and a reduction in carbon emissions has produced an increase in demand for alternative fuel sources. Current strategies for reducing the environmental impact of natural gas combustion in gas turbine engines used for power generation experience such hurdles as flashback, lean blow-off and combustion dynamics. These issues will continue as turbines are presented with coal syngas, gasified coal, biomass, LNG and high hydrogen content fuels. As it may be impractical to physically test a given turbine on all of the possible fuel blends it may experience over its life cycle, the need to predict fuel interchangeability becomes imperative. This study considers a number of historical parameters typically used to determine fuel interchangeability. Also addressed is the need for improved reaction mechanisms capable of accurately modeling the combustion of natural gas alternatives. Offers an understanding of the basic physical, chemical, and aerodynamic processes associated with gas turbine combustion and their relevance and application to combustor performance and design. This book details practical approaches to combustor design for the clean burning of alternative liquid fuels derived form oil shades, tar sands, and coal.

The paper reports on an attempt to apply Meurer's film vaporization combustion method (M-method), originally developed for diesel motors, to the combustion chambers of gas turbines. (In the M-method, instead of distributing the fuel in the air, it is laid on the wall of the combustion chamber and evaporated, mixed, and fired by means of the appropriate movement of air - the evaporation rate, as a function of the air velocity, and gas and flame temperature, providing an additional control element for the combustion process.) The three points primarily considered are: (1) The formation of a fuel film of sufficient surface extent on the wall. (2) The evaporation of the fuel from this wall and its molecular mixing with the combustion air at sufficiently low temperatures and delay times to minimize cracking. (3) The injection of the fuel-air mixture into a combustion zone in which oxidation reactions may first take place. (Author).

Industrial Gas Turbines: Performance and Operability explains important aspects of gas turbine performance such as performance deterioration, service life and engine emissions. Traditionally, gas turbine performance has been taught from a design perspective with insufficient attention paid to the operational issues of a specific site. Operators are not always sufficiently familiar with engine performance issues to resolve operational problems and optimise performance. Industrial Gas Turbines: Performance and Operability discusses the key factors determining the performance of compressors, turbines, combustion and engine controls. An accompanying engine simulator CD illustrates gas turbine performance from the perspective of the operator, building on the concepts discussed in the text. The simulator is effectively a virtual engine and can be subjected to operating conditions that would be dangerous and damaging to an engine in real-life conditions. It also deals with issues of engine deterioration, emissions and turbine life. The combined use of text and simulators is designed to allow the reader to better understand and optimise gas turbine operation. Discusses the key factors in determining the perfomance of compressors, turbines, combustion and engine controls Explains important aspects of gas and turbine perfomance such as service life and engine emissions Accompanied by CD illustrating gas turbine performance, building on the concepts discussed in the text

With regard to both the environmental sustainability and operating efficiency demands, modern combustion research has to face two main objectives, the optimization of combustion efficiency and the reduction of pollutants. This book reports on the combustion research activities carried out within the Collaborative Research Center (SFB) 568 “Flow and Combustion in Future Gas Turbine Combustion Chambers” funded by the German Research Foundation (DFG). This aimed at designing a completely integrated modeling and numerical simulation of the occurring very complex, coupled and interacting physico-chemical processes, such as turbulent heat and mass transport, single or multi-phase flows phenomena, chemical reactions/combustion and radiation, able to support the development of advanced gas turbine chamber concepts

Lean premixed combustion systems have been established as state-of-the-art technology for heavy-duty gas turbines, allowing for low pollutant emissions. However, lean premixed combustion is also associated with thermoacoustic instabilities. Thus, modeling of the key performance parameters - pollutant emissions and thermoacoustics - has become mandatory in the design process. The present thesis contributes to the modeling of those key parameters. The objective was to describe and validate the methods for the prediction of emissions (NO_xand CO) and thermoacoustics. A low order approach for prediction of NO_xemissions and a high fidelity CFD-based approach for the combined prediction of emissions and thermoacoustics are presented within this work. The methods are selected and developed based on analysis of the current state of the art.