

Solid Propellant Chemistry Combustion And Motor Interior Ballistics Progress In Astronautics And Aeronautics

The development of an erosive burning model for solid rocket motors using direct numerical simulation Brian A. McDonald 93 Pages Directed by Dr. Suresh Menon. A method for developing an erosive burning model for use in solid propellant design-and-analysis interior ballistics codes is described and evaluated. Using Direct Numerical Simulation, the primary mechanisms controlling erosive burning (turbulent heat transfer, and finite rate reactions) have been studied independently through the development of models using finite rate chemistry, and infinite rate chemistry. Both approaches are calibrated to strand burn rate data by modeling the propellant burning in an environment with no cross-flow, and adjusting thermophysical properties until the predicted regression rate matches test data. Subsequent runs are conducted where the cross-flow is increased from M=0.0 up to M=0.8. The resulting relationship of burn rate increase versus Mach Number is used in an interior ballistics analysis to compute the chamber pressure of an existing solid rocket motor. The resulting predictions are compared to static test data. Both the infinite rate model and the finite rate model show good agreement when compared to test data. The propellant considered is an AP/HTPB with an average AP particle size of 37 microns. The finite rate model shows that as the cross-flow increases, near wall vorticity increases due to the lifting of the boundary caused by the side injection of gases from the burning propellant surface. The point of maximum vorticity corresponds to the outer edge of the APd-binder flame. As the cross-flow increases, the APd-binder flame thickness becomes thinner ; however, the point of highest reaction rate moves only slightly closer to the propellant surface. As such, the net increase of heat transfer to the propellant surface due to finite rate chemistry affects is small. This leads to the conclusion that augmentation of thermal transport properties and the resulting heat transfer increase due to turbulence dominates over combustion chemistry in the erosive burning problem. This conclusion is advantageous in the development of future models that can be calibrated to heat transfer conditions without the necessity for finite rate chemistry. These results are considered applicable for propellants with small, evenly distributed AP particles where the assumption of premixed APd-binder gases is reasonable.

The first book to present a full-color visual panorama of combustion images along with explanatory and tutorial overviews.

Detailed knowledge of the gas-phase reactions which occur during propellant ignition and combustion are required to understand and model these processes. If detailed models were available, modification of propellant formulations for improved combustion behavior could be achieved with much less trial-and-error testing. Furthermore, detailed models could be used to generate simplified kinetics schemes for use in propellant models. Without a firm basis for these simplified kinetic schemes, the kinetic parameters are often adjusted to fit burning rate and ignition data; thus the propellant models are reduced to sophisticated curve fits to experimental data. The present research program, centers around the development and application of a microprobe, mass spectrometer (MPMS) system to study the gas phase chemistry of solid propellant ingredients and solid propellants during heating by a CO2 laser and during steady combustion. The MPMS system uses quartz microprobes with orifice sizes of 100 microns or less to withdraw gases from the region above the sample material. Through a two stage pumping system, the sample is delivered to a quadrupole mass spectrometer for analysis. Sampling is continuous throughout the combustion event so that species profiles of stable intermediates above the sample are obtained during the experiments. Investigations of Novel Energetic Materials to Stabilize Rocket Motors Solid Propellant Chemistry Combustion and Motor Interior Ballistics 1999

The Development of an Erosive Burning Model for Solid Rocket Motors Using Direct Numerical Simulation

Thermochemical Aspects of Combustion

Detailed knowledge of the gas-phase reactions which occur during propellant ignition and combustion are required to understand and model these processes. If detailed models were available, modification of propellant formulations for improved combustion behavior could be achieved with much less trial-and-error testing. Furthermore, detailed models could be used to generate simplified kinetics schemes for use in propellant models. The present research program, centers around the development and application of a microprobe, mass spectrometer (MPMS) system to study the gas phase chemistry of solid propellant ingredients and solid propellants during heating by a CO2 laser and during steady combustion. The MPMS system uses quartz microprobes with orifice sizes of 100 microns or less to withdraw gases from the region above the sample material. Through a two stage pumping system, the sample is delivered to a quadrupole mass spectrometer for analysis. Sampling is continuous throughout the combustion event so that species profiles of stable intermediates above the sample are obtained during the experiments. In addition to the MPMS system, existing experimental methods to be used in the work include high speed direct photography, high speed schlieren photography, microthermocouple probes and photodiodes (for first visible light).

Nanomaterials in Rocket Propulsion Systems covers the fundamentals of nanomaterials and examines a wide range of innovative applications, presenting the current state-of-the-art in the field. Opening with a chapter on nano-sized energetic materials, the book examines metal nanoparticles-based fuels, ballistic modifiers, stabilizers and catalysts as the components of rocket propellants. Hydrogen storage materials for rocket propulsion based on nanotubes are then discussed, as are nano-porous materials and metal organic frameworks, nano-gelled propellants, nano-composite ablators and ceramic nano-composites. Other applications examined include high thermal conductivity metallic nano-composite nozzle liners, nano-emitters for Coulomb propulsion of space-crafts, and highly thermostable nano-ceramics for rocket motors. The book finishes with coverage of combustion of nano-sized rocket fuels, nano-particles and their combustion in micro- and nano-electromechanical systems (MEMS/NEMS), plasma propulsion and nano-scale physics. Users will find this to be a valuable resource for academic and government institutions, professionals, new researchers and graduate students working in the application of nanomaterials in the aerospace industry. Provides a detailed overview of different types of nanomaterials used in rocket propulsion, highlighting different situations in which different materials are used Demonstrates the use of new nanomaterial concepts, allowing for an increase in payload capacity or a decrease in launch mass Explores a range of applications using metal nanopowders, presenting a panorama on cutting-edge, technological developments The purpose of this book is to discuss, at the graduate level, the methods of performance prediction for chemical rocket propulsion. A pedagogical presentation of such methods has been unavailable thus far and this text, based upon lectures, fills this gap. The first part contains the energy-minimization to calculate the propellant-combustion composition and the subsequent computation of rocket performance. While incremental analysis is for high performance solid motors, equilibrium-pressure analysis is for low performance ones. Both are detailed in the book's second part for the prediction of ignition and tail-off transients, and equilibrium operation. Computer codes, adopting the incremental analysis along with erosive burning effect, are included. The material is encouraged to be used and presented at lectures. Senior undergraduate and graduate students in universities, as well as practicing engineers and scientists in rocket industries, form the readership.

Innovative Energetic Materials: Properties, Combustion Performance and Application

The Chemistry of Propellants

An Introduction to Propellants

Solid Propellant Chemistry, Combustion, and Motor Interior Ballistics

A Gallery of Combustion and Fire

The book is a treatise on solid propellants in nine chapters, covering the history, chemistry, energetics, processing and characterization aspects of composite solid propellants, internal ballistics, advanced solid propellants, safety, quality and reliability and homogenous or double base propellants. The book also traces the evolution of solid propellant technology in ISRO for launch vehicles and sounding rockets. There is a detailed table of contents, expanded index, glossary, exhaustive references and questions in each chapter. It can be used as a textbook for science and engineering students, as a reference book for researchers and as a companion to scientists and engineers working in the research, development and production areas of solid propellants.

Boron-Based Fuel-Rich Solid Rocket Propellant Technology is a professional book that systematically introduces the latest research progress for boron-based fuel-rich solid propellants. It covers surface modifications, coating and agglomerating techniques, granulation, and characterization of amorphous boron powders, and its application to fuel-rich solid rocket propellants. Technologies for controlling the processing methods and combustion performance of fuel-rich propellants are examined, and the book concludes with a summary of the research progress in boron-based fuel-rich solid propellants and a look forward to the foreseeable development trends of military applications.

Solid propellant is the most important energy source for rocket, missile and other weapons to launch, and is the key material to realize the firing range and damage effect of weapons. In order to meet the requirements of weapon application, the overall requirements for the energy performance, combustion performance, mechanical performance, storage performance, safety performance and process performance of solid propellant are put forward. Therefore, there are many challenges to fully meet the requirements of solid propellant and apply it to weapons. In recent years, with the development of material science, computational science and experimental technology, there are many reports about the composition, structure, performance research and prediction of solid propellants.This book reviews the research progress in solid propellant binder, energy performance prediction and thermodynamic calculation, combustion gas flow and combustion performance regulation, material storage performance research and safety performance simulation, and discusses the key development direction. The summary and prospect of this paper are expected to provide guidance, reference and inspiration for relevant researchers to carry out the research of solid propellant.This book is suitable for researchers, technicians and students who are engaged in solid propellant, weapons, chemistry and other work to read, for reference in specific research work. Due to the limited level of editors and short time, some problems are inevitable. We regret for some problems.

A Comprehensive Survey of Energetic Materials

Combustion Chemistry of Composite Solid Propellants Based on Nitramine and High Energetic Binders

Combustion of Energetic Materials

Propellants Manufacture, Hazards, and Testing

The Chemistry and Technology of Solid Rocket Propellants (A Treatise on Solid Propellants)

Chemical and thermal structure of flame of solid propellants based on nitramine (HMX or RDX) and azide polymer (GAP or BAMO-AMMO) has been investigated at pressure of 0.5 and 1.0 MPa by method of molecular-beam mass spectrometry and microthermocouple. Chemical flame structure of pure nitramines at atmospheric pressure has been obtained too. Burning rate has been measured. The probe method of sampling of species from flame allowing to detect products of propellant decomposition (including nitramine vapor) in the zone adjacent to the burning surface has been developed. Eleven species, including nitramine vapor, have been detected in the zone adjacent to the burning surface in the case of nitramine/GAP propellants. Experiments showed that there are two zones of chemical reactions in flame of nitramine/GAP propellants and one zone in flame of nitramine/BAMO-AMMO propellants. Species concentrations have been determined at different distances from the burning surface. Temperature profiles in the combustion wave of solid propellants have been measured. An extensive plateau on the temperature profiles was not observed. Data obtained can be used for creation and validation of combusting model for propellants on the basis of nitramine and azide polymer.

A modern pedagogical treatment of the latest industry trends in rocket propulsion, developed from the authors' extensive experience in both industry and academia. Students are guided along a step-by-step journey through modern rocket propulsion, beginning with the historical context and an introduction to top-level performance measures, and progressing on to in-depth discussions of the chemical aspects of fluid flow combustion thermochemistry and chemical equilibrium, solid, liquid, and hybrid rocket propellants, mission requirements, and an overview of electric propulsion. With a wealth of homework problems (and a solutions manual for instructors online), real-life case studies and examples throughout, and an appendix detailing key numerical methods and links to additional online resources, this is a must-have guide for senior and first year graduate students looking to gain a thorough understanding of the topic along with practical tools that can be applied in industry.

Solid Propellant Rocket Research

Energetics of Propellant Chemistry

Solid Propellant Rocket Research

Chemical Rockets

Thermal Decomposition and Combustion of Explosives and Propellants

Fundamentals of Solid Propellant Combustion

This book, a translation of the French title Technologie des Propergols Solides, offers otherwise unavailable information on the subject of solid propellants and their use in rocket propulsion. The fundamentals of rocket propulsion are developed in chapter one and detailed descriptions of concepts are covered in the following chapters. Specific design methods and the theoretical physics underlying them are presented, and finally the industrial production of the propellant itself is explained. The material used in the book has been collected from different countries, as the development of this field has occurred separately due to the classified nature of the subject. Thus the reader not only has an overall picture of solid rocket propulsion technology but a comprehensive view of its different developmental permutations worldwide.

Solid Propellant Chemistry Combustion and Motor Interior Ballistics 1999AIAAThe Chemistry and Technology of Solid Rocket Propellants (A Treatise on Solid Propellants)Allied Publishers

Propellants contain considerable chemical energy that can be used in rocket propulsion. Bringing together information on both the theoretical and practical aspects of solid rocket propellants for the first time, this book will find a unique place on the readers' shelf providing the overall picture of solid rocket propulsion technology. Aimed at students, engineers and researchers in the area, the authors have applied their wealth of knowledge regarding formulation, processing and evaluation to provide an up to date and clear text on the subject.

Science and Technology Challenges

Proceedings

Memorial Tributes

Boron-Based Fuel-Rich Propellant

Mechanics and Chemistry of Solid Propellants

This unique book investigates the synthesis, kinetics, and thermal decomposition properties and processing of energy-producing materials used in propellants, explosives, pyrotechnic, and gas-generating compositions. Thermal Decomposition and Combustion of Explosives and Propellants provides several mechanisms and stages for the thermal decomposition and combustion reactions of most flammable compounds and their mixtures, such asaliphatic and aromatic nitrocompounds, nitramines, nitroesters, organic azides, furazanes, tetrazols, difluoroamines, polynitrous heterocycles, and onium salts. The authors examine the classic problem of the dependence of explosive activity on molecular structure, using applications to predict the stability, compatibility, and the stabilization of explosives and propellant components. They also offer experimental results examining factors such as subsurface decomposition, evaporation, and dispersion of materials, which can be used to control combustion of condensed systems. Providing several approaches to stability, safety, and controlled combustion of flammable substances, Thermal Decomposition and Combustion of Explosives and Propellants is a multi-dimensional resource for graduate students, researchers and professionals interested in chemical kinetics, the combustion and synthesis of high-energy materials, criminal forensics, and the field of explosives, powders, and solid rocket propellants.

This third edition of the classic on the thermochemical aspects of the combustion of propellants and explosives is completely revised and updated and now includes a section on green propellants and offers an up-to-date view of the thermochemical aspects of combustion and corresponding applications. Clearly structured, the first half of the book presents an introduction to pyrodynamics, describing fundamental aspects of the combustion of energetic materials, while the second part highlights applications of energetic materials, such as propellants, explosives and pyrolants, with a focus on the phenomena occurring in rocket motors. Finally, an appendix gives a brief overview of the fundamentals of aerodynamics and heat transfer, which is a prerequisite for the study of pyrodynamics. A detailed reference for readers interested in rocketry or explosives technology.

Mechanics and Chemistry of Solid Propellants is a collection of papers presented at the Fourth Symposium on Naval Structural Mechanics, held in Purdue University, Lafayette, Indiana on April 19–21, 1965 under the joint sponsorship of the Office of Naval Research and Purdue University. The contributors consider the development and utilization of solid propellants. This book is composed of 22 chapters that cover the many branches of studies that touch upon the science and technology of solid propellants. Some chapters present the mathematical and physical theories underlying the behavior of solid propellants, such as nonlinear and linear theories of viscoelasticity. Other chapters are devoted to advances in solid propellant binder chemistry; combustion and its effects on the structural integrity of the solid propellant grain; and design and other engineering problems. This book will be of value to scientists, engineers, and researchers who are interested in the diverse applications of solid propellants.

Solid Rocket Propellants

Propellant Chemistry

A Study of the Gas Phase Chemistry of Solid Propellants Using a Microprobe Mass Spectrometer (MPMS) System: Preliminary Results for Solid Fuels (HTPB/Zecorez and BAMO/NMMO) Single-Base Propellant (M10) and an RDX-Based Propellant (BLX-9).

A History of Jet Propulsion, Including Rockets

Rocket Propulsion

This edited book contains state-of-the-art information associated with energetic material combustion. There are twelve topical areas, including: Reaction Kinetics of Energetic Materials (Solid, Liquid, and Gel Propellants); Recycling of Energetic Materials; Combustion Performance of Hybrid and Solid Rocket Motors; Ignition and Combustion of Energetic Materials; Energetic Material Defects and Rocket Engine Flowfields; Metal Combustion; Pyrolysis and Combustion Processes of New Ingredients and Applications; Theoretical Modeling and Numerical Simulation of Combustion Processes of Energetic Materials; Combustion Diagnostic Techniques; Propellant and Rocket Motor Stability; Commercial Applications of Energetic Materials (Airbags, Gas Generators, etc.); and Thermal Insulation and Ablation Processes.

*Chemistry at Extreme Conditions covers those chemical processes that occur in the pressure regime of 0.5–200 GPa and temperature range of 500–5000 K and includes such varied phenomena as comet collisions, synthesis of super-hard materials, detonation and combustion of energetic materials, and organic conversions in the interior of planets. The book provides an insight into this active and exciting field of research. Written by top researchers in the field, the book covers state of the art experimental advances in high-pressure technology, from shock physics to laser-heating techniques to study the nature of the chemical bond in transient processes. The chapters have been conventionally organised into four broad themes of applications: biological and bioinorganic systems; Experimental works on the transformations in small molecular systems; Theoretical methods and computational modeling of shock-compressed materials; and experimental and computational approaches in energetic materials research. * Extremely practical book containing up-to-date research in high-pressure science * Includes chapters on recent advances in computer modelling * Review articles can be used as reference guide*

The Chemistry of Propellants is a collection of papers and comments presented at the meeting on "The Chemistry of Propellants , held in Paris, France on June 8-12, 1959, organized by the AGARD Combustion and Propulsion Panel. This book is organized into six parts encompassing 25 chapters that serve as an introduction to the broad and important subject of propellant chemistry and propulsion applications. The first part deals with the sources, availability, and comparative costing of propulsion system. The second and third parts discuss the theoretical, thermodynamic, and experimental aspects of liquid and solid propellants. The fourth part examines the main problems concerning preparation, storage, and use of propellants for ramjet, while the fifth part looks into the factors leading to deposits in jet engines and some of the consequences of their existence. The sixth part covers the advantages of the high energy chemical propellants, including fluorine and hydrogen. Combustion and propulsion scientists and researchers will find this book beneficial.

A Study of the Gas Phase Chemistry of Solid Propellants Using a Microprobe Mass Spectrometer (MPMS) System: Initial Development of the MPMS System

Proceedings of the Fourth Symposium on Naval Structural Mechanics, Purdue University, Lafayette, Indiana, April 19-21, 1965

An Introduction to the Engineering of Rockets

Chemistry at Extreme Conditions

Propellants and Explosives

The book follows a unified approach to present the basic principles of rocket propulsion in concise and lucid form. This textbook comprises of ten chapters ranging from brief introduction and elements of rocket propulsion, aerothermodynamics to solid, liquid and hybrid propellant rocket engines with chapter on electrical propulsion. Worked out examples are also provided at the end of chapter for understanding uncertainty analysis. This book is designed and developed as an introductory text on the fundamental aspects of rocket propulsion for both undergraduate and graduate students. It is also aimed towards practicing engineers in the field of space engineering. This comprehensive guide also provides adequate problems for audience to understand intricate aspects of rocket propulsion enabling them to design and develop rocket engines for peaceful purposes.

Developed and expanded from the work presented at the New Energetic Materials and Propulsion Techniques for Space Exploration workshop in June 2014, this book contains new scientific results, up-to-date reviews, and inspiring perspectives in a number of areas related to the energetic aspects of chemical rocket propulsion. This collection covers the entire life of energetic materials from their conceptual formulation to practical manufacturing; it includes coverage of theoretical and experimental ballistics, performance properties, as well as laboratory-scale and full system-scale, handling, hazards, environment, ageing, and disposal. Chemical Rocket Propulsion is a unique work, where a selection of accomplished experts from the pioneering era of space propulsion and current technologists from the most advanced international laboratories discuss the future of chemical rocket propulsion for access to, and exploration of, space. It will be of interest to both postgraduate and final-year undergraduate students in aerospace engineering, and practicing aeronautical engineers and designers, especially those with an interest in propulsion, as well as researchers in energetic materials.

This is the 17th Volume in the series Memorial Tributes compiled by the National Academy of Engineering as a personal remembrance of the lives and outstanding achievements of its members and foreign associates. These volumes are intended to stand as an enduring record of the many contributions of engineers and engineering to the benefit of humankind. In most cases, the authors of the tributes are contemporaries or colleagues who had personal knowledge of the interests and the engineering accomplishments of the deceased. Through its members and foreign associates, the Academy carries out the responsibilities for which it was established in 1964. Under the charter of the National Academy of Sciences, the National Academy of Engineering was formed as a parallel organization of outstanding engineers. Members are elected on the basis of significant contributions to engineering theory and practice and to the literature of engineering or on the basis of demonstrated unusual accomplishments in the pioneering of new and developing fields of technology. The National Academies share a responsibility to advise the federal government on matters of science and technology. The expertise and credibility that the National Academy of Engineering brings to that task stem directly from the abilities, interests, and achievements of our members and foreign associates, our colleagues and friends, whose special gifts we remember in this book.

Chemical Rocket Propulsion

Properties, Combustion, and Technology Aspects

Solid Propellant Chemistry, Combustion, and Motor Interior Ballistics, Volume 185

A Meeting Organised by the AGARD Combustion and Propulsion Panel

Chemistry and Combustion Instability in Solid Propellant Rocket Motors

This book focuses on the combustion performance and application of innovative energetic materials for solid and hybrid space rocket propulsion. It provides a comprehensive overview of advanced technologies in the field of innovative energetic materials and combustion performance, introduces methods of modeling and diagnosing the aggregation/agglomeration of active energetic metal materials in solid propellants, and investigates the potential applications of innovative energetic materials in solid and hybrid propulsion. In addition, it also provides step-by-step solutions for sample problems to help readers gain a good understanding of combustion performance and potential applications of innovative energetic materials in space propulsion. This book serves as an excellent resource for researchers and engineers in the field of propellants, explosives, and pyrotechnics.

This document is the final report of the Caltech Multidisciplinary University Research Initiative (MURI), "Investigations of Novel Energetic Materials to Stabilize Rocket Motors," ONR Contract No. N00014-95-1-1338. With a one-year no-cost extension, the program covered the period 1 October 1995 to 30 September 2001 and involved Principal Investigators at nine Universities. In addition, for three years, funds from another source supported research by seven Russian research groups. Participants in the Caltech MURI provided technical oversight of that work. A second MURI devoted to the same general subject was carried out at the University of Illinois at Urbana- Champaign (UIUC). The two programs were largely complementary. Some of the sections in this report have been co-authored by representatives of both MURIs. Similarly, the final report of the UIUC MURI will contain some duplication of material covered in this document. The Caltech MURI was a multidisciplinary program devoted to research on fundamental problems of the chemistry, combustion and gas dynamics of novel energetic propellants and their unsteady behavior in rocket motors. This program achieved significant progress towards the ultimate overall objective of research in this field, to identify and quantify the influences of propellant composition on the stability of motions in a solid propellant rocket motor. To attain that objective it is essential to support cross-disciplinary effort between propellant chemists and researchers; combustion researchers; and researchers concentrating on the dynamics of solid rocket combustors. This MURI program was the first sustained effort to accomplish the necessary collaborations among faculty and students in universities, with participation by representatives of government laboratories and industry; in the many respects described in this report the program has been highly successful.

THE DEFINITIVE INTRODUCTION TO ROCKET PROPULSION THEORY AND APPLICATIONS The recent upsurge in global government and private spending and in space flight events has resulted in many novel applications of rocket propulsion technology.

Rocket Propulsion Elements remains the definitive guide to the field, providing a comprehensive introduction to essential concepts and applications. Led by industry veteran George P. Sutton and by Professor Oscar Biblarz, this book provides interdisciplinary coverage including thermodynamics, aerodynamics, flight performance, propellant chemistry and more. This thoroughly revised ninth edition includes discussion and analysis of recent advances in the field, representing an authoritative reference for students and working engineers alike. In any engineering field, theory is only as useful as it is practical; this book emphasizes relevant real-world applications of fundamental concepts to link "thinking" and "doing". This book will help readers: Understand the physics of flight and the chemistry of propulsion Analyze liquid, solid, gas, and hybrid propellants, and the engines they fuel Consider high-temperature combustion, stability, and the principles of electric and chemical propulsion Dissect the workings of systems in common use around the world today Delve into the latest advances in materials, systems, propellants, and more Broad in scope, rich in detail, and clear in explanation, this seminal work provides an unparalleled foundation in aerospace engineering topics. Learning through the lens of modern applications untangles complex topics and helps students fully grasp the intricacies on a more intuitive level. Rocket Propulsion Elements, Ninth Edition merges information and utility building a solid foundation for innovation.

Nanomaterials in Rocket Propulsion Systems

Performance Prediction and Internal Ballistics Design

Fundamentals of Rocket Propulsion

Solid Rocket Propulsion Technology

Rocket Propulsion Elements

Both Jet-engine propelled aircraft and long-range rockets were first successfully flown during World War II. This led to rapid post-war improvements in both, and within two decades we had supersonic airplanes, communication satellites, and trips to the moon. Unmanned probes to Mars and the outer planets followed, as well as the International Space Station. The technology behind these advances is described, along with short biographies of key pioneers. Problems at high Mach numbers are reviewed. Possible future developments are discussed. More technical details, including mathematics, are in an appendix.