Design And Analysis On Scramjet Engine Inlet

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Scientific and Technical Aerospace Reports Springer p="" This highly informative book offers a comprehensive overview of the fundamentals of propulsion. The book focuses on foundational topics in propulsion, namely gas dynamics, turbomachinery, and combustion to more complex subjects such as practical design aspects of aircraft engines and thermodynamic aspects and analysis. It also includes pedagogical aspects such as end-of-chapter problems and worked examples to augment learning and self-testing. This book is a useful reference for students in the area of mechanical and aerospace engineering. Also, scientists and engineers working in the areas of aerospace propulsion and gas dynamics find this book a valuable addition. ^

An Engineering Method for the Design and Analysis of Waverider Derived Hypersonic Vehicles AIAA

Design and Analysis of a Mach 3 Dual Mode Scramjet Combustor

Quasi-one-dimensional Scramjet Combustor Flow Solver Using the Numerical Propulsion System Simulation John Wiley & Sons Various aspects of hypersonic vehicles are being rapidly explored for improved functionality. One of the main areas of consideration is the fueling of a Supersonic Combusting Ramjet (scramjet) engine. Using Computational Fluid Dynamics (CFD), computer simulations can be performed to analyze the flow physics of a scramjet. In this research, an optimization code, Dakota, is integrated with the CFD to optimize a set of parameters to maximum thrust. In this study, the fuel injection and combustion is replaced with heat sources. This simplification greatly reduces the computational requirements. Additionally, the 3D geometry is reduced to an axisymmetric 2D geometry because three dimension effects like mixing and combustion are not being modeled. With this simplified model, the optimization and CFD algorithm is executed to find the heat addition for maximum thrust. Different optimization methods have been explored to reduce computational times. A genetic algorithm was selected because of its robust abilities. Additionally, a sampling algorithm was selected because of its abilities to explore the whole design space. Furthermore, the sampling method enables additional studies, such as sensitivity studies, to be completed. In addition to optimization studies, calibration studies are performed to obtain the heat source values that correspond to a given experimental wall pressure distribution. Knowledge of the optimized heat distribution will assist in the optimization of fueling splits and injector locations for a more detailed combustion investigation in which similar optimization techniques can be applied.

Fundamentals of Propulsion AIAA

Describes the development and implementation of an engineering method that can be used for the design and analysis of scramjets. Calculates the length of the scramjet combustor duct based on the coupled solution of 1D conservation of mass, momentum, and energy equations with heat addition, combustion, and friction. Introduces the design of a minimum length nozzle, which is used as an integral part of the hypersonic configuration. Seeks to document this design methodology and describe in detail the integration of the core elements as they relate to the overall hypersonic vehicle construction process.

Thermal-structural Design Study of an Airframe-integrated Scramjet Springer "The numerical modeling of supersonic combustion ramjet (scramjet) engine flow paths plays an important role in the design of hypersonic air-breathing propulsion systems. Due to the complexity of the flow field physics and limited experimental data, numerical models possess uncertainties which should be addressed to improve the prediction accuracy of the simulations. In this study, the effect of turbulence model closure coefficient uncertainty on the Reynolds-averaged Navier-Stokes solution of a scramjet isolator and scramjet strut fuel injector flow field is investigated with an uncertainty quantification and sensitivity analysis study for commonly used turbulence models. Turbulence models considered in this work are Menter-BSL, Menter-SST, Spalart-Allmaras, and Wilcox-2006 k-[omega]. Simulations were carried out using NASA's VULCAN flow solver. Nonintrusive polynomial chaos theory was used for efficient propagation of uncertainty, and Sobol indices were utilized to quantify the global non-linear sensitivity of various solution metrics to the variation of each closure coefficient. The scramjet isolator study considered the shock location, skin friction coefficient, and integrated axial shear force as output metrics of interest. The output metrics of interest for the strut fuel injector study included the integrated quantities of mixing efficiency, circulation, total pressure recovery, and one-dimensional Mach number, as well as the pointwise vorticity and eddy viscosity distributions, and were evaluated at three crossflow planes. The results obtained were compared to available experimental data as well as to previous work focusing on relevant flow problems and other sources of solution uncertainty. Influential sets of closure coefficients were identified for each turbulence model, with the Kármán and diffusion constants being the most prominent. The results presented in this work are expected to assist future efforts aimed at reducing the uncertainty in the numerical design of scramjet engine components through the identification of closure coefficients and physical aspects of the flow that warrant further investigation"--Abstract, page iii.

Scramjet Propulsion Cambridge University Press Low speed operation of a dual mode scramjet engine is important to the development of a two stage to orbit reusable launch vehicle. This study investigates the Mach 3 operation of a dual mode scramjet engine. SRGULL, a one-dimensional cycle code for scramjet engines, and VULCAN, a computational fluid dynamics code capable of solving reacting flows, are used in this study. Staged injection is investigated to allow more heat release at a low flight Mach number condition so that more thrust can be achieved and inlet unstart

is avoided. The nominal case has one injector located 1.067 meters downstream of the inlet with a fuel equivalence ration of 0.488. An increase in thrust of 11.6% is shown in this study by injecting a fuel equivalence ratio of 0.437 upstream and a fuel equivalence ratio of 0.369 at a location 0.8 meters downstream of the first injector.

Hypersonic Vehicles BoD – Books on Demand

High speed propulsion systems typically possess relatively simple geometry but the complexity involved in the flow characteristics makes their analysis a challenging task. The current research work introduces a reduced order analytical model for a steady operation of dual mode SCRamjet (Supersonic Combustion Ramjet) propulsion system at design and off-design conditions. The model hopes to reduce analysis time and complexity to carry out parametric sweep studies for preliminary design of SCRamjet engines. The analytical model splits the analysis of SCRamjet engine into five interactive components namely: inlet, isolator, injector, burner and nozzle. Each component is modelled using physics of gas-dynamics and semi-empirical relations. The flow characterization of each component and their interactions are modelled carefully based on observed physical phenomenon reported in the existing literature. The model is developed on MATLAB platform providing flexibility to design a parametrized SCRamjet geometry and to select its free stream and fueling conditions for the analysis. The analytical model proposed in the current work is validated with various experimental and computational data of individual components and its reliability for predicting the flow characteristics inside a SCRamjet propulsion system is discussed in detail.

Hypersonic Airbreathing Propulsion Springer Nature

An almost entirely self-contained engineering textbook primarily for use in undergraduate and graduate courses in airbreathing propulsion. It provides a broad and basic introduction to the elements needed to work in the field as it develops and grows. Homework problems are provided for almost every individual subject. An extensive array of PC-based user-friendly computer programs is provided in order to facilitate repetitious and/or complex calculations. Annotation copyright by Book News, Inc., Portland, OR

Design and Multifidelity Analysis of Dual Mode Scramjet Compression System Using Coupled NPSS and Fluent Simulation Design and Analysis of a Mach 3 Dual Mode Scramjet CombustorLow speed operation of a dual mode scramjet engine is important to the development of a two stage to orbit reusable launch vehicle. This study investigates the Mach 3 operation of a dual mode scramjet engine. SRGULL, a one-dimensional cycle code for scramjet engines, and VULCAN, a computational fluid dynamics code capable of solving reacting flows, are used in this study. Staged injection is investigated to allow more heat release at a low flight Mach number condition so that more thrust can be achieved and inlet unstart is avoided. The nominal case has one injector located 1.067 meters downstream of the inlet with a fuel equivalence ration of 0.488. An increase in thrust of 11.6% is shown in this study by injecting a fuel equivalence ratio of 0.437 upstream and a fuel equivalence ratio of 0.369 at a location 0.8 meters downstream of the first injector.Design-oriented Analysis of Scramjet Combustor Flowfield Using Combined UNS/PNS ProcedureScramjet Propulsion

Hypersonic airbreathing engines mark a potential future development of the aerospace industry and immense efforts have been taken in gaining knowledge in them for the past decades .The physical phenomenon occurring at the hypersonic flow regime makes the design and performance prediction of a scramjet engine hard. Though cuttingedge simulation tools fight their way toward accurate prediction of the environment, the time consumed by the entire process in designing and analyzing a scramjet engine and its component may be exorbitant. A multi-fidelity approach for designing a scramjet with a cruising Mach number of 6 is detailed in this research where high-order simulations are applied according to the physics involved in the component. Two state-of-the-art simulation tools were used to take the aerodynamic and propulsion disciplines into account for realistic prediction of the individual components as well as the entire scramjet. The specific goal of this research is to create a virtual environment to design and analyze a hypersonic, two-dimensional, planar inlet and isolator to check its operability for a dual-mode scramjet engine. The dual mode scramjet engine starts at a Mach number of 3.5 where it operates as a ramjet and accelerates to Mach 6 to be operated as a scramjet engine. The intercomponent interaction between the compression components with the rest of the engine is studied by varying the fidelity of the numerical simulation according to the complexity of the situation. Efforts have been taken to track the transition Mach number as it switches from ramjet to scramjet. A complete scramjet assembly was built using the Numerical Propulsion Simulation System (NPSS) and the performance of the engine was evaluated for various scenarios. Different numerical techniques were opted for varying the fidelity of the analysis with the highest fidelity consisting of 2D RANS CFD simulation. The interaction between the NPSS elements with the CFD solver is governed by the top-level assembly solver of NPSS. The importance of intercomponent interactions are discussed.The methodology used in this research for design and analysis, should add up to provide an efficient way for estimating the design and off-design operating modes of a dual mode scramjet engine.

Future Spacecraft Propulsion Systems Springer Science & Business Media

The ongoing development of military aerospace platforms requires continuous technology advances in order to provide the nation's war fighters with the desired advantage. Significant advances in the performance and efficiency of jet and rocket propulsion systems are strongly dependent on the development of lighter more durable high-temperature materials. Materials development has been significantly reduced in the United States since the early 1990s, when the Department of Defense (DOD), the military services, and industry had very active materials development activities to underpin the development of new propulsion systems. This resulted in significant improvements in all engine characteristics and established the United States in global propulsion technology. Many of the significant advances in aircraft and rocket propulsion have been enabled by improved materials and, materials manufacturing processes. To improve efficiency further, engine weight must be reduced while preserving thrust. Materials Needs and Research and Development Strategy for Future Military Aerospace Propulsion Systems examines whether current and planned U.S. efforts are sufficient to meet U.S. military needs while keeping the U.S. on the leading edge of propulsion technology. This report considers mechanisms for the timely insertion of materials in propulsion systems and how these mechanisms might be improved, and describes the general elements of research and development strategies to develop materials for future military aerospace propulsion systems. The conclusions and recommendations asserted in this report will enhance the efficiency, level of effort, and impact of DOD materials development activities.

National Academies Press

Demand for high-speed propulsion has renewed development of the supersonic combustion ramjet engine (Scramjet engine) for hypersonic flight applications.

INVESTIGATION OF THE LOW SPEED FIXED GEOMETRY SCRAMJET. 'INLET DESIGN PRACTICE MANUAL'

Significant progress has been achieved during the first year of this Challenge effort, in developing and simulating configurations which highlight the main scramjet inlet flow path alternatives. In particular, three different types of inward-turning inlets have been explored, including the rectangular cross-section, scoop and 'jaws' designs. Each flowpath has been discretized and subjected to inviscid laminar and turbulent analyses with highly-scalable solvers at design and off design conditions ranging from Mach 6 to Mach 10. Viscous/inviscid interactions are observed to have a profound impact on the flow, giving rise to distortion of the velocity profile at the exit of the inlet (entrance of the isolator/combustor component). For the jaws approach, the effects of angle-of-attack and yaw have been studied A complex pattern of low and high total pressure

variation is observed, suggesting strategies for the subsequent fuel injection processes. For the rectangular cross-section dual-plane compression inlet, combustor integration has been accomplished with finite-rate chemical kinetics. The efftct on mixing characteristics of numerous injection strategies, both upstream and/or in the interior of a wall cavity, are examined. The injection process is observed to yield a separation shock, bow shock and Mach disk, as well as a reattachment shock. Potential phenomena that might generate instabilities and subsequent unstart have been identified, as are locations of high temperature, unburnt fuel gases and combustion efficiency. In a separate, but related effort, simulations have also been performed to yield data for flight-test experiments (HiFIRE program) to ensure survivability of mass capture diagnostic devices.

Advances in Engineering Design

The flow field inside a scramjet engine combustor involves complex phenomena such as fuel-air mixing, combustion chemistry, and flow separation. In order to determine the properties of the flow along the length of the combustor, mass, momentum and energy balance equations are solved simultaneously using a numerical method. While a full three dimensional computational simulation gives detailed results with high order of accuracy, it demands a great amount of time and computational resource. A low order analysis produces a fast overall picture of the combustor operation which in turn provides valuable information suitable for the preliminary design process. This research work aims to describe the analysis process of the scramjet combustor in which a quasi-one-dimensional, multi-species, reacting real gas model of the flow is developed to address the limitations in previous researches. The Numerical Propulsion System Simulation (NPSS), into which the NASA Chemical Equilibrium with Applications (CEA) code is integrated, is utilized as the platform to perform the analysis. The analytical model is validated by comparison with experimental data from previous researches. The results obtained by this method are expected to shed some light on the advantages of using detailed chemistry with lower order analysis to calculate scramjet engine performance.

Coupling Computational Fluid Dynamics Analysis and Optimization Techniques for Scramjet Engine Design

This book presents select proceedings of the International Conference on Future Learning Aspects of Mechanical Engineering (FLAME 2018). The book covers mechanical design areas such as computational mechanics, finite element modeling, computer aided designing, tribology, fracture mechanics, and vibration. The book brings together different aspects of engineering design, and will be useful for researchers and professionals working in this field.

Active Cooling Design for Scramjet Engines Using Optimization Methods

Proposes, develops, and analyzes a hypersonic engine model in three phases: phase 1, the forebody-inlet-isolator design and analysis; phase 2, the combustor-diffuser-nozzle design and analysis; and phase 3, the integration of results from phases 1 and 2 with an optimization perspective. Conducts engine performance studies with the emphasis on manipulating these geometric design parameters to derive engine models of superior thrust performance while maintaining functional aerodynamic engine shapes. Focuses in part on the independent performance validation of this hypersonic engine model.

Reduced-order Analysis of Dual Mode Supersonic Combustion Ramjet Propulsion System

An overview is presented of fundamental and practical insights obtained on scramjet flowpaths during a three year Challenge Project utilizing high fidelity methodologies and advanced postprocessing techniques. Simulations are employed to analyze the principal phenomena, including inlet distortion, fuel-air mixing, ignition and thrust generation at freestream Mach numbers between 6 and 8. In addition to guiding the evolution and execution of high-speed ground and flight experiments, the discovery objective of the project identifies trends and suggests optimization strategies for rapid response and kinetic kill hypersonic vehicles. Three inlet designs are considered, including the traditional rectangular cross-section configuration and two streamline traced variants denoted Scoop and Jaws, each attached to a corresponding cavity-based flame-holding combustor. The simulations reveal the characteristic distortion signature of each design. Parametric analyses provide insight into major performance issues, including the effects of distortion on combustion, injector port configurations and gaseous versus liquid (multi-phase) injection of simple and complex fuels. Some results are consistent with intuition: for example, streamwise-staggered and spanwise-interlaced injectors enhance diffusive mixing. Other findings are not intuitive and point to competing constraints.

Validation of the Forebody Design of a Ramjet-scramjet Propulsion System Using Computational Fluid Dynamics

Computer programs have been written to aid the design and analysis of 2-D, axisymmetric, and 3-D supersonic inlets. This report presents the fundamental analytic techniques, the use and operation of the computer programs, and the application to the design of supersonic inlets. The programs are written in FORTRAN IV for use on the 7094 high speed digital computer. The 2-D and axisymmetric programs presented herein are written for generalized inviscid supersonic internal flow problems with uniform or non-uniform inlet entry conditions for entropy, total enthalpy, pressure, Mach number and flow direction. The program capabilities include the intersections and reflections of both family waves, the formation of shocks or expansions at corners, the formation of shocks by coalescence of waves from smooth walls, and the formation of contact discontinuities. The 3-D programs presented herein are written for the calculation of the inviscid supersonic flow fields associated with basic elements of 3-D supersonic inlets. The methods utilized exact and linearized supersonic flow theory with engineering approximations to yield solutions to the following unit problems; delta wing flow, conical shock interacting with a plane surface, plane shock interacting with a conical surface, and the interaction of two different conical flow fields.

Ramjet Engines

This book presents a step-by-step methodology for the design of ramjet engines. It explores ramjet combustion, provides guidelines on how to size the engines, and discusses performance analysis. The book begins with an introduction to ramjet design, including fundamental definitions in the field. It then discusses ramjet engine performance, and fuels which can be used. Several types of ramjet engines are then explored, and guidelines for their design are presented, including flame holders, injectors, and combustors. Finally, the book concludes with a discussion of the types of materials which should be used for ramjet engines. This book is of interest to engine designers and engineers, researchers, and graduate students, as it collates research in a succinct, clear guide to the issue of designing ramjet engines.

High Fidelity Design Oriented Scramjet Propulsion Flowpath Analysis

Scramjet Propulsion Explore the cutting edge of HAP technologies with this comprehensive resource from an international leader in her field Scramjet Propulsion: A Practical Introduction delivers a comprehensive treatment of hypersonic air breathing propulsion and its applications. The book covers the most up-to-date hypersonic technologies, like endothermic fuels, fuel injection and flameholding systems, high temperature materials, and TPS, and offers technological overviews of hypersonic flight platforms like the X-43A, X-51A, and HiFIRE. It is organized around easy-to-understand explanations of technical challenges and provides extensive references for the information contained within. The highly accomplished author provides readers with a fulsome description of the theoretical underpinnings of hypersonic technologies, as well as critical design and technology issues affecting hypersonic air breathing propulsion technologies. The book's combination of introductory theory and advanced instruction about individual hypersonic engine components is ideal for students and practitioners in fields as diverse as hypersonic vehicle and propulsion development for missile defense technologies, launch aerospaceplanes, and civilian transports. Over 250 illustrations and tables round out the material. Readers will also learn from: A thorough introduction to hypersonic flight, hypersonic vehicle concepts, and a review of fundamental principles in hypersonic air breathing propulsion Explorations of the

aerothermodynamics of scramjet engines and the design of scramjet components, as well as hypersonic air breathing propulsion combustors and fuels Analyses of dual-mode combustion phenomena, materials structures, and thermal management in hypersonic vehicles, and combined cycle propulsion An examination of CFD analysis, ground and flight testing, and simulation Perfect for researchers and graduate students in aerospace engineering, Scramjet Propulsion: A Practical Introduction is also an indispensable addition to the libraries of engineers working on hypersonic vehicle development seeking a state-of-the-art resource in one of the most potentially disruptive areas of aerospace research today.

Aerothermodynamic Flow Phenomena of the Airframe-integrated Supersonic Combustion Ramjet

In the aviation field there is great interest in high-speed vehicle design. Hypersonic vehicles represent the next frontier of passenger transportation to and from space. However, several design issues must be addressed, including vehicle aerodynamics and aerothermodynamics, aeroshape design optimization, aerodynamic heating, boundary layer transition, and so on. This book contains valuable contributions focusing on hypervelocity aircraft design. Topics covered include hypersonic aircraft aerodynamic and aerothermodynamic design, especially aeroshape design optimization, computational fluid dynamics, and scramjet propulsion. The book also discusses high-speed flow issues and the challenges to achieving the dream of affordable hypersonic travel. It is hoped that the information contained herein will allow for the development of safe and efficient hypersonic vehicles.