Operation Of A Cryogenic Rocket Engine

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Experimental Investigation of High Frequency Combustion Instability in Cryogenic Oxygen-hydrogen Rocket Engines BoD – Books on Demand

The National Bureau of Standards Boulder Laboratories was on September 5-7, 1956 again host to a national conference on cryogenic engineering. Supported financially by many of the leading industrial firms currently active in this rapidly expanding field, the conference, second of its kind, attracted more than 400 scientists and engineers from all parts of the world. This attendance was evidence of the present interest and growth in cryogenic engineering, a field which has as yet not found a satisfactory place within the bounds of existing professional societies. In all but two cases the Proceedings contain the summary or entire text of the paper presented at the confer ence. Forty-nine papers were presented at seven separate sessions. These sessions were divided into the following general topics: Cryogenic Processes Cryogenic Equipment Cryogenic Properties Cryogenic Applications Bubble Chambers The division in some cases had to be somewhat arbitrary since several papers could have been classified under more than one general topic. To make the Proceedings more valuable to the reader, an attempt was made to record the general discussion which followed each paper. Unfortunately, however, the recording devices were not sensitive enough for clear reproduction. The discussions, therefore, have not been included in the Proceed ings.

Extreme Temperature Operation of a Hydrazine Rocket Engine Springer-Praxis

Presentation of space flight mechanics intended for the technically-minded high school student and layman.

Rocket and Spacecraft Propulsion Cuvillier

Nuclear rocket engines employ hydrogen, a cryogenic liquid, as a propellant in order to obtain a system with a high specific impulse. Since hydrogen is also an excellent moderator of neutrons, it provides a reactivity contribution which must be taken into consideration in the design of a reactor and in its programmed operation. The reactivity worth of hydrogen is a function of its density distribution. The prediction of this quantity was facilitated by heat transfer experiments, which were simulated on a digital computer. Pressure oscillations associated with the twophase flow of hydrogen were simulated by means of a spring-mass model. (auth).

Liquid Rocket Valve Components Springer Science & Business Media

As part of an Army Material Research Agency program to evaluate candidate rocket motor cases for future Army missile systems, and evaluation of three 12.5 in. motor cases was performed. The cases were made from AISI 301 stainless steel by a cryogenic stretch forming process. After dimensional and radiographic inspections, each case was subjected to a hydrostatic burst pressurization test at -65 F. The performance of the cases under the low temperature pressurization tests was entirely satisfactory. The performance of the three cases under pressurization at low temperature has demonstrated that the cryogenic stretch forming process is a potential fabrication technique for the manufacture of motor cases for future Army missile systems. Further work is necessary to demonstrate better dimensional control and also to demonstrate that the process can be used to fabricate larger sized high strength cases. (Author).

The Rocket Company Springer Science & Business Media

Fiberoptics could offer several major benefits for cryogenic liquid-fueled rocket engines, including lightning immunity, weight reduction, and the possibility of implementing a number of new measurements for engine condition monitoring. The technical feasibility of using fiberoptics in the severe environments posed by cryogenic liquid-fueled rocket engines was determined. The issues of importance and subsequent requirements for this use of fiberoptics were compiled. These included temperature ranges, moisture embrittlement succeptability, and the ability to withstand extreme shock and vibration levels. Different types of optical fibers were evaluated and several types of optical fibers' ability to withstand use in cryogenic liquid-fueled rocket engines was demonstrated through environmental testing of samples. This testing included: cold-bend testing, moisture embrittlement testing, temperature cycling, temperature extremes testing, vibration testing, and shock testing. Three of five fiber samples withstood the tests to a level proving feasibility, and two of these remained intact in all six of the tests. A fiberoptic bundle was also tested, and completed testing without breakage. Preliminary cabling and harnessing for fiber protection was also demonstrated. According to cable manufacturers, the successful -300 F cold bend, vibration, and shock tests are the first instance of any major fiberoptic cable testing below roughly -55 F. This program has demonstrated the basic technical feasibility of implementing optical fibers on cryogenic liquid-fueled rocket engines, and a development plan is included highlighting requirements and issues for such an implementation. Delcher, R. C. Unspecified Center FEASIBILITY ANALYSIS; FIBER OPTICS; LIQUID PROPELLANT ROCKET ENGINES; TECHNOLOGY ASSESSMENT; BEND TESTS; CRYOGENIC ROCKET PROPELLANTS; LOW TEMPERATURE TESTS; OPTICAL FIBERS; SHOCK TESTS; VIBRATION TESTS...

Experimental and Theoretical Investigations of the Physical Processes Related to the Retention Capability of a Double Screen Element against Liquid Hydrogen in Earth's Gravity and in Microgravity with Respect to the Applied Stimuli Springer

The revised edition of this practical, hands-on book discusses the launch vehicles in use today throughout the world, and includes the latest details on advanced systems being developed, such as electric and nuclear propulsion. The author covers the fundamentals, from the basic principles of rocket propulsion and vehicle dynamics through the theory and practice of liquid and solid propellant motors, to new and future developments. He provides a serious exposition of the principles and practice of rocket propulsion, from the point of view of the user who is not an engineering specialist.

Advances in Cryogenic Engineering Springer Science & Business Media

As the subject of tribology comprises lubrication, friction and wear of contact components highly relevant to practical applications, it challenges scientists from chemistry, physics and materials engineering around the world on todays sophisticated experimental and theoretical foundation to complex interdisciplinary research. Recent results and developments are preferably presented and evaluated in the context of established knowledge. Consisting of eleven chapters divided into the four parts of Lubrication and Properties of Lubricants, Boundary Lubrication Applications, Testing and Modeling, and Sustainability of Tribosystems, this textbook therefore merges basic concepts with new findings and approaches. Tribology Fundamentals and Advancements, supported by competent authors, aims to convey current research trends in the light of the state of the art to students, scientists and practitioners and help them solve their problems.

Development of Ultra-high Strength Rocket Motor Cases by Cryogenic Stretch Forming and Cooled Solid Propellant Rocket Nozzles Springer Science & Business Media

Particularly in the upper stage development of rockets (launchers), gravity dominated fluid motion in upper stage tanks (sloshing) during flight represents an undesired dynamic effect. On the one hand the sloshing forces lead to disturbances, which have to be compensated by the reaction control system. On the other hand, when cryogenic fluids are considered, the fluctuations in tank pressure may be critical under some circumstances compromising the structural stability of the tank. In this field, the utilization of cryogenic propellants represents a high challenge to layout and design of the propulsion components including the propellant tanks. This work deals with two effects that are directly coupled to the sloshing content inside the propellant tank. To investigate these effects a dedicated test setup has been developed. At first, the damping characteristics of sloshing cryogenic nitrogen - which is used as a substitute for the rocket propellants liquid hydrogen and liquid oxygen - are determined. The results are correlated to the theory based on storable propellants. The main part of this work is linked to a characteristic pressure drop inside the propellant tank caused by the sloshing liquid. For the effect to occur, the tank must be pressurized to enable the formation of a thermal stratification below the liquid surface. Sloshing leads to the mixing of liquid in this region with subcooled liquid from the bulk. This affects the decrease of the temperature at the free surface leading to the condensation of superheated vapor. Thus, the pressure in the tank must decreases. Three different pressurization concepts are introduced in this work; self-pressurization where the tank is pressurized by evaporating liquid caused by the heat flowing into the tank. Furthermore, the tank is pressurized with gaseous nitrogen taken from an external gas bottle and at last gaseous helium from an external supply is used for pressurization purpose. By the application of helium as no

Advanced Cryogenics Springer

This book presents the operational aspects of the rocket engine on a test facility. It will be useful to engineers and scientists who are in touch with the test facility. To aerospace students it shall provide an insight of the job on the test facility. And to interested readers it shall provide an impression of this thrilling area of aerospace.

Advances in Cryogenic Engineering AIAA

This report gives an account of progress for the period December 21, 1960 to January 20, 1961. The information is presented in two (2) sections. The first section describes the work performed on Task A, Development of Ultra-High Strength Rocket Cases by Cryogenic Stretch Forming. The second section reports progress on Task B, Cooled Solid Propellant Rocket Nozzles.

Reusable Booster System Springer Science & Business Media

The objective of the program is to produce experimental, flight-weight rocket motor cases of a configuration similar to Pershing, by the cryogenic stretch-forming process. Previous work demonstrated the feasibility of producing high-strength rocket cases by cryogenci stretchforming. The present follow-on program is being undertaken to evaluate the process for producing a specific, predetermined, complex-configuration motor case at the strength level previously achieved (240,000 psi nominal yield stress). Details of this configuration include skirts, forward igniter port, conical aft closure, and nozzle attachment ring. (Author).

Applied Cryogenic Engineering National Academies Press

The 1959 Cryogenic Engineering Conference Committee is pleased to pre sent the papers of the 1959 Cryogenic Engineering Conference. We are fortunate to have had the University of California at Berkeley, Ca!., as our host for the fifth national meeting of this kind. The move to the West Coast for this past Cryogenic Engineering Conference was prompted in part by the large concentration of missile activities which are to be found there. Recognition of cryogenic operations and techniques in the mis sile field is given in many of the included papers. The University of California was certainly wen suited for such a meeting as this because it was here that much early work was done in cryogenics. This pioneering in cryogenics is still evident today in the operation of the 72-in. bub ble chamber at the Lawrence Radiation Laboratory. The Cryogenic Engineering Conference salutes the missile industry and the cryogenic pioneers of yesterday and today at the University of California. Special thanks must go to Dr. D. N. Lyon from the Low-Temperature Laboratory of the University of California, who as chairman of the 1959 Cryogenic Engineering Conference Committee has worked tirelessly to increase the stature of this conference. vii ACKNOWLEDGMENT The Cryogenic Engineering Conference Committee is deeply grateful for the continued support and interest of the following organizations who made the 1959 Cryogenic Engineering Conference possible. Aerojet-General Corporation A. D. Little, Inc.

Advances in Cryogenic Engineering National Academies Press

Support from the National Science Foundation has made it possible for the tenth annual Cryogenic Engineering Conference, hosted by the University of Pennsylvania and capably directed by K. R. Atkins and his staff, to emphasize the major international advances in cryogenic engineering. This specific emphasis resulted in a final program of over one hundred papers and has made it necessary to publish the proceedings of the conference in two volumes. The first volume will be similar in nature to previous volumes in this series, while the second volume will feature the international aspect of the conference program. The latter volume, because of this distinction, will be entitled International Advances in Cryogenic Engineering. As in the past, the Cryogenic Engineering Conference Committee gratefully acknow ledges the assistance of all the dedicated workers in the cryogenic field who have contributed their time in reviewing the preliminary papers for the program and the final manuscripts for this volume. Since the list of participants in this thankless task numbers well over one hundred, any attempt to acknowledge their individual contributions in the limited space available would be practically impossible.

Advanced Cryogenic Solid Hybrid Rocket Engine Developments: Concept and Test Results Springer Nature

Self-sustaining pressure oscillations in the combustion chamber, or combustion instability,

is a commonly encountered and potentially damaging phenomenon in liquid propellant rocket engines (LPREs). In the high-frequency variety of combustion instability, the pressure oscillations in the combustion chamber take on the form and frequency of an acoustic resonance mode of the combustion chamber volume. The most common mode in naturally occurring instability, and also the most destructive, is the first tangential mode, with acoustic gas oscillations oriented transversally to the direction of propellant injection. The instability is driven by the coupling between acoustic oscillations and unsteady energy release from combustion. The mechanisms through which injection and combustion firstly respond to the acoustic field, and secondly feed energy back into the acoustic field have not yet been fully characterised. Shear coaxial-type injectors are common in LPREs. Past experimental and numerical research efforts have investigated the interaction between this type of injector and transverse acoustic fields. Some experimental efforts have successfully forced transverse acoustic modes and studied their influence on shear coaxial injection under LPRE-like conditions. Acoustic forcing of coaxially injected LOx/H2 has previously been conducted only at low pressures and injection performance levels. This work addresses the lack of experimental data available for the interaction of shear coaxial injection of LOx/H2 with acoustics under conditions representative of industrial engines. A new experimental rocket combustor, designated 'BKH', was developed for investigating the response of a reacting spray of coaxially injected LOx/H2 to an acoustic field. For characterising the response, simultaneous high-speed recordings of both backlit shadowgraph and hydroxyl radical (OH*) chemiluminescence imaging have been captured through optical access windows. The operating conditions of BKH extend to conditions more representative of actual LPREs than has previously been achieved with LOx/H2 in studies of flame-acoustic interaction. BKH was run at pressures of 40 or 60 bar, which correspond to subcritical and supercritical thermo-physical regimes for oxygen. Hydrogen injection temperature was ambient, around 290 K, or cryogenic, around 50 K. An array of multiple injectors was used to better represent real engines. A system for modulating the nozzle exhaust flow was used to induce acoustic perturbations inside the combustion chamber. Two types of perturbation were applied to the near-injection region; oscillating acoustic pressure, and oscillating transverse acoustic velocity. BKH was used to investigate how subcritical or supercritical pressure level and ambient or cryogenic hydrogen injection temperature influence the interaction of acoustic pressure or velocity with injection and combustion processes. Shadowgraph imaging reveals up to 70% reduction in the length of the oxygen jet when subjected to acoustic velocity of amplitude approaching that of the hydrogen injection velocity. Furthermore, the mode of jet breakup changes from its natural growth-and-detachment behaviour to a 'transverse stripping' mechanism. OH* imaging reveals a corresponding decrease in the extent of the flame, and increase in emission intensity. When subjected to acoustic pressure, OH* emission from the flame was observed to fluctuate in phase with pressure. Thus, responses to both acoustic pressure and velocity have been observed in BKH, which together may form the basis of a coupling mechanism for driving natural combustion instability in LPREs.

Cryogenic Fluids in Nuclear Propulsion Systems Cuvillier Verlag

"Drawing on his wide experience of both designing and building hardware and teaching the fundamentals of rocket propulsion to undergraduate students, the author has produced a work that is particularly accessible to those without a formal engineering background who are studying or working in the space industry."--BOOK JACKET.

Rocket and Spacecraft Propulsion CRC Press

This book is intended for students and engineers who design and develop liquid-propellant rocket engines, offering them a guide to the theory and practice alike. It first presents the fundamental concepts (the generation of thrust, the gas flow through the combustion chamber and the nozzle, the liquid propellants used, and the combustion process) and then qualitatively and quantitatively describes the principal components involved (the combustion chamber, nozzle, feed systems, control systems, valves, propellant tanks, and interconnecting elements). The book includes extensive data on existing engines, typical values for design parameters, and worked-out examples of how the concepts discussed can be applied, helping readers integrate them in their own work. Detailed bibliographical references (including books, articles, and items from the “gray literature”) are provided at the end of each chapter, together with information on valuable resources that can be found online. Given its scope, the book will be of particular interest to undergraduate and graduate students of aerospace engineering.

Taming Liquid Hydrogen AIAA

"The Cryogenic Star Tracking Attitude Regulation System (CSTARS) utilizes a Scientific CMOS (sCMOS) CIS2521F image sensor operating at cryogenic temperatures (77K) to track stars. This is used aboard a sounding rocket for attitude control of the CIBER-2 experiment payload. Standard optical sensors used traditionally for astronomical observations, such as CCD’s, have a low responsivity at cryogenic temperatures. In contrast, CMOS sensors do not exhibit this issue. During flight, the CIBER-2 primary imaging sensors and CSTARS are co-boresighted to the same telescope, all of which are cooled down to cryogenic temperatures. The attitude feed- back provided by CSTARS ensures that CIBER-2 remains aligned with the desired starfield. This work has integrated and tested the necessary control and acquisition system and has determined for the first time the responsivity and minimum detectable star magnitude for a sCMOS image sensor operating at cryogenic temperatures. This paper describes the design, verification, and testing methodologies used in the current work, which are also applicable to similar systems and image sensors. CSTARS was flown along with CIBER-2 on April 16th 2023. The results leading up to and during this flight have proven the readiness of sCMOS sensors for cryogenic space flight operation."--Abstract.

Operation of a Cryogenic Rocket Engine Springer Science & Business Media

"A fictionalized account of the challenges faced by a group of seven investors and their engineering team in developing a low-cost, reusable, Earth-to orbit launch vehicle. The marketing, regulatory, and technical problems are explored ... "cover p. [4].

Chemical Rockets, and Flame and Explosives Technology Springer Science & Business Media

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.

Cryogenic Operation of SCMOS Image Sensors

"Scientific CMOS image sensors have lower read noise and dark current than charge coupled devices. They are also uniquely qualified for operation at cryogenic temperatures due to their MOSFET pixel architecture. This paper follows the design of a cryogenic imaging system to be used as a star tracking rocket attitude regulation system. The detector was proven to retain almost all its sensitivity at cryogenic temperatures with acceptably low read noise. Once the star tracker successfully maintains rocket attitude during the flight of the CIBER-2 experiment, the technology readiness level of scientific CMOS detectors will advance enough that they could see potential applications in deep space imaging experiments."--Abstract.