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SPO9XN - HAILEY HINTON

A description of the implicit filtering algorithm, its convergence theory and a new MATLAB® implementation.

Portable electronic devices have made a profound impact on our society and economy due to their widespread use for computation, communications, and entertainment. The performance and autonomy of these devices can be greatly improved if their operation can be powered using energy that is harvested from the ambient environment. As a step towards that goal, this thesis explored the feasibility of developing miniaturized Stirling engines for harvesting waste heat. A mesoscale (palmtop-size) gamma-type Stirling engine, with a total volume of about 165 cubic centimeters, was manufactured using conventional machining techniques. The engine was able to sustain steady-state operation at relatively low temperature differentials (between 20 degrees Celsius and 100 degrees Celsius) and generated a few millijoules of mechanical energy at frequencies ranging from 200 to 500 revolutions per minute. Subsequently, the gamma-type engine was transformed into a Ringbom engine...

Some 200 years after the original invention, internal design of a Stirling engine has come to be considered a specialist task, calling for extensive experience and for access to sophisticated computer modelling. The low parts-count of the type is negated by the complexity of the gas processes by which heat is converted to work. Design is perceived as problematic largely because those interactions are neither intuitively evident, nor capable of being made visible by laboratory experiment. There can be little doubt that the situation stands in the way of wider application of this elegant concept. Stirling Cycle Engines re-visits the design challenge, doing so in three stages. Firstly, unrealistic expectations are dispelled: chasing the Carnot efficiency is a guarantee of disappointment, since the Stirling engine has no such pretentions. Secondly, no matter how complex the gas processes, they embody a degree of intrinsic similarity from engine to engine. Suitably exploited, this means that a single computation serves for an infinite number of design conditions. Thirdly, guidelines resulting from the new approach are condensed to high-resolution design charts – nomograms. Appropriately designed, the Stirling engine promises high thermal efficiency, quiet operation and the ability to operate from a wide range of heat sources. Stirling Cycle Engines offers tools for expediting feasibility studies and for easing the task of designing for a novel application. Key features: Expectations are re-set to realistic goals. The formulation throughout highlights what the thermodynamic processes of different engines have in common rather than what distinguishes them. Design by scaling is extended, corroborated, reduced to the use of charts and fully Illustrated. Results of extensive computer modelling are condensed down to high-resolution Nomograms. Worked examples feature throughout. Prime movers (and coolers) operating on the Stirling cycle are of increasing interest to industry, the military (stealth submarines) and space agencies. Stirling Cycle Engines fills a gap in the technical literature and is a comprehensive manual for researchers and practitioners. In particular, it will support effort world-wide to exploit potential for such applications as small-scale CHP (combined heat and power), solar energy conversion and utilization of low-grade heat.

The aim of this project was to develop a proof-of-concept Stirling Engine and heat cell for use in the mining industry, primarily for underground applications. In particular, the Stirling engine, being an external combustion engine, offers the potential to operate on stored heat in low-oxygen or inert underground atmospheres. This makes it attractive for rescue vehicles, which are required to operate in such environments. A prototype Stirling engine with power output in the 15kW range was constructed and tested. Experimental measurements showed that this output was not achieved. While the basic thermodynamic principles of the design were valid, achieved output was well below the required value, due largely to the following issues: Heat source: Because of budgetary constraints it was not possible to use the molten salt bath-type of heat source for which the heat exchanger was designed. Instead a gas burner was used which did not transfer sufficient heat into the engine. Working gas pressure: The heat to mechanical energy conversion process efficiency depends strongly on the pressure of the working gas. Because of a problem with seal design the pressure for the test was only 7% of the design value. Seals: It is apparent that the perennial problem of seal design in Stirling engines was not solved in this implementation. Gas pressure could not be maintained, and even with the modest pressure used, friction, mainly caused by the seals produced unacceptable losses. These losses would be exacerbated if the working gas pressure was raised. The conclusion is that, because of the lack of commercial Stirling cycle-based products and the difficulty experienced in this project in overcoming the problem of high temperature seal implementation to produce a working prototype, the short term potential of the Stirling engine for mine rescue applications is limited.

This book gathers selected papers from Artificial Intelligence and Industrial Applications (A2IA'2020), the first installment of an annual international conference organized by ENSAM-Meknes at Moulay Ismail University, Morocco. The 29 papers presented here were carefully reviewed and selected from 141 submissions by an international scientific committee. They address various aspects of artificial intelligence such as digital twin, multiagent systems, deep learning, image processing and analysis, control, prediction, modeling, optimization and design, as well as AI applications in industry, health, energy, agriculture, and education. The book is intended for AI experts, offering them a valuable overview and global outlook for the future, and highlights a wealth of innovative ideas and recent, important advances in AI applications, both of a foundational and practical nature. It will also appeal to non-experts who are curious about this timely and important subject.

The Regenerator and the Stirling Engine examines the basic scientific and engineering principles of the Regenerator and the Stirling engine. Drawing upon his own research and collaboration with engine developers, Allan J Organ offers solutions to many of the problems which have prevented these engines operating at the levels of efficiency of which they are theoretically capable. The Regenerator and the Stirling Engine offers practising engineers and designers specific guidelines for building in optimum thermodynamic performance at the design stage. COMPLETE CONTENTS: Bridging the gap The Stirling cycle Heat transfer – and the price Similarity and scaling; Energetic similarity In support of similarity Hausen revised Connectivity and thermal shorting Real particle trajectories – natural co-ordinates The Stirling regenerator The Ritz rotary regenerator Compressibility effects Regenerator flow impedance Complex admittance – experimental corroboration Steady-flow Cf–Nre correlations inferred from linear-wave analysis Optimization Part I: without the computer Optimization Part II: cyclic steady state Elements of combustion Design study Hobby-horse Origins Appendices

Here is everything you need to know to build your own low temperature differential (LTD) Stirling engines without a machine shop. These efficient hot air engines will run while sitting on a cup of hot water, and can be fine-tuned to run from the heat of a warm hand. Four engine projects are included. Each project includes a parts list, detailed drawings, and illustrated step-by-step assembly instructions. The parts and materials needed for these projects are easily obtained from local hardware stores and model shops, or ordered online. Jim Larsen's innovative approach to Stirling engine design helps you achieve success while keeping costs low. All of the engines described in this book are based on a conventional pancake style LTD Stirling engine format. These projects introduce the use of Teflon tubing as an alternative to expensive ball bearings. An entire chapter is devoted to the research and testing of various materials for hand crafted bearings. The plans in this book are detailed and complete. This collection of engine designs is a stand-alone companion to Jim Larsen's first book, "Three LTD Stirling Engines You Can Build Without a Machine Shop."

A lucid introduction to the Stirling Engines, written primarily for laymen with little back ground in Mechanical Engineering. The book covers the historical aspects, the conceptual details as well as the brief steps in making a simple working Stirling Engine model.

DEFINITION AND NOMENCLATURE A Stirling engine is a mechanical device which operates on a closed regenerative thermodynamic cycle with cyclic compression and expansion of the working fluid at different temperature levels. The flow of working fluid is controlled only by the internal volume changes, there are no valves and, overall, there is a net conversion of heat to work or vice-versa. This generalized definition embraces a large family of machines with different functions; characteristics and configurations. It includes both rotary and reciprocating systems utilizing mechanisms of varying complexity. It covers machines capable of operating as a prime mover or power system converting heat supplied at high tempera ture to output work and waste heat at a lower temperature. It also covers work-consuming machines used as refrigerating systems and heat pumps abstracting heat from a low temperature source and delivering this plus the heat equivalent of the work consumed to a higher tem perature. Finally it covers work-consuming devices used as pressure generators compressing a fluid from a low pressure to a higher pres sure. Very similar machines exist which operate on an open regen erative cycle where the flow of working fluid is controlled by valves. For convenience these may be called Ericsson engines but unfortunate ly the distinction is not widely established and regenerative machines of both types are frequently called 'Stirling engines'.

My history with stirling engines. -- A brief history of stirling engines. -- The stirling engine explained. -- What makes a good stirling engine? -- Working with aluminum. -- Working with acrylic. -- Thermoforming vinyl. -- Tools needed for these projects. -- Engine #1 - the reciprocating stirling engine. -- Engine #2 - horizontal flywheel magnetic drive stirling engine. -- Engine #3 - vertical flywheel magnetic drive stirling engine. -- Appendices.

Stirling Convertor Regenerators addresses the latest developments and future possibilities in the science and practical application of Stirling engine regenerators and technology. Written by experts in the vanguard of alternative energy, this invaluable resource presents integral scientific details and design concepts associated with Stirling converter regenerators. Content is reinforced with novel insights and remarkable firsthand experience that the authors and their colleagues acquired while working at the National Aeronautics and Space Administration (NASA) and other leading organizations. Apply NASA Experience & Experimentation Intrigued by its special potential to improve energy generation, NASA has been working on Stirling technology since 1980—first for automotive applications, and later for use in generating auxiliary power during space missions. Now, after three decades of development, the Department of Energy and NASA and its contractors have developed a high-efficiency Stirling radioisotope generator (SRG), and NASA plans to launch such a Stirling engine/alternator for use in deep space. With contributions from top experts in their fields, this reference offers a rare insider's perspective that can greatly benefit engineers, scientists, and even students who are currently working in R&D for Stirling machines, as well as other burgeoning areas of alternative power generation—particularly solar and wind technologies. This book is a significant resource for anyone working on application of porous materials in filters, catalytic convertors, thermal energy storage, electronic cooling, and more.

Presents eleven projects demonstrating how to build simple, fun, and educational Stirling engines from available kits.

For Stirling engines to enjoy widespread application and acceptance, not only must the fundamental operation of such engines be widely understood, but the requisite analytic tools for the stimulation, design, evaluation and optimization of Stirling engine hardware must be readily available. The purpose of this design manual is to provide an introduction to Stirling cycle heat engines, to organize and identify the available Stirling engine literature, and to identify, organize, evaluate and, in so far as possible, compare non-proprietary Stirling engine design methodologies. This report was originally prepared for the National Aeronautics and Space Administration and the U. S. Department of Energy.

This book is about the Stirling engine and its development from the heavy cast-iron machine of the nineteenth century into the efficient high-speed engine of today. It is not a handbook: it does not tell the reader how to build a Stirling engine. It is rather the history of a research effort spanning nearly fifty years, together with an outline of principles, some technical details and descriptions of the more important engines. No one will dispute the position of Philips as the pioneer of the modern Stirling engine. Hence the title of the book, hence also the contents, which are confined largely to the Philips work on the subject. Valuable work has been done elsewhere but this is discussed only marginally in order to keep the book within a reasonable size. The book is addressed to a wide audience on an academic level. The first two chapters can be read by the technically interested layman but after that some engineering background and elementary mathematics are generally necessary.Heat engines are traditionally the engineer's route to thermodynamics: in this context, the Stirling engine, which is the simplest of all heat engines, is more suited as a practical example than either the steam engine or the internal-combustion engine. The book is also addressed to historians of technology, from the viewpoint of the twentieth century revival of the Stirling engine as well as its nineteenth century origins.

This research is in the area of Thermal Energy Conversion, more specifically, in the conversion of solar thermal energy. This form of renewable energy can be utilised for production of power by using thermo-mechanical conversion systems - Stirling engines. The advantage of such the systems is in their capability to work on low and high temperature differences which is created by the concentrated solar radiation. To design and build efficient, high performance engines in a feasible period of time it is necessary to develop advanced mathematical models based on thermodynamic analysis which accurately describe heat and mass transfer processes taking place inside machines. The aim of this work was to develop such models, evaluate their accuracy by calibrating them against published and available experimental data and against more advanced three-dimensional Computational Fluid Dynamics models. The refined mathematical models then were coupled to Genetic Algorithm optimisation codes to find a rational set of engine's design parameters which would ensure the high performance of machines. The validation of the developed Stirling engine models demonstrated that there was a good agreement between numerical results and published experimental data. The new set of design parameters of the engine obtained from the optimisation procedure provides further enhancement of the engine performance. The mathematical modelling and design approaches developed in this study with the use of optimization procedures can be successfully applied in practice for creation of more efficient and advanced Stirling engines for power production.

While much effort in Stirling engine development is placed on making the high-temperature region of the Stirling engine warmer, this research explores methods to lower the temperature of the cold region by improving heat transfer in the cooler. This paper presents heat transfer coefficients obtained for a Stirling engine heat exchanger with oscillatory flow. The effects of oscillating frequency and input heat rate on the heat transfer coefficients are evaluated and details on the design and development of the heat exchanger test apparatus are also explained. Featured results include the relationship between overall heat transfer coefficients and oscillation frequency which increase from 21.5 to 46.1 Wm-2K-1 as the oscillation frequency increases from 6.0 to 19.3 Hz. A correlation for the Nusselt number on the inside of the heat exchange tubes in oscillatory flow is presented in a concise, dimensionless form in terms of the kinetic Reynolds number as a result of a statistical analysis. The test apparatus design is proven to be successful throughout its implementation due to the usefulness of data and clear trends observed. The author is not aware of any other publicly-available research on a Stirling engine cooler to the extent presented in this paper. Therefore, the present results are analyzed on a part-by-part basis and compared to segments of other research; however, strong correlations with data from other studies are not expected. The data presented in this paper are part of a continuing effort to better understand heat transfer properties in Stirling engines as well as other oscillating flow applications.

As part of the SP-100 program, a phase 1 effort to design a free-piston Stirling engine (FPSE) for a space dynamic power conversion system was completed. SP-100 is a combined DOD/DOE/-NASA program to develop nuclear power for space. This work was completed in the initial phases of the SP-100 program prior to the power conversion concept selection for the Ground Engineering System (GES). Stirling engine technology development as a growth option for SP-100 is continuing after this phase 1 effort. Following a review of various engine concepts, a single-cylinder engine with a linear alternator was selected for the remainder of the study. The relationships of specific mass and efficiency versus temperature ratio were determined for a power output of 25 kWe. This parametric study was done for a temperature ratio range of 1.5 to 2.0 and for hot-end temperatures of 875 K and 1075 K. A conceptual design of a 1080 K FPSE with a linear alternator producing 25 kWe output was completed. This was a single-cylinder engine designed for a 62,000 hour life and a temperature ratio of 2.0. The heat transport systems were pumped liquid-metal loops on both the hot and cold ends. These specifications were selected to match the SP-100 power system designs that were being evaluated at that time. The hot end of the engine used both refractory and superalloy materials; the hot-end pressure vessel featured an insulated design that allowed use of the superalloy material. The design was supported by the hardware demonstration of two of the component concepts - the hydrodynamic gas bearing for the displacer and the dynamic balance system. The hydrodynamic gas bearing was demonstrated on a test rig. The dynamic balance system was tested on the 1 kW RE-1000 engine at NASA Lewis. Penswick, L. Barry and Beale, William T. and Wood, J. Gary Unspecified Center ENGINE DESIGN; HEAT TRANSFER; PISTON ENGINES; SPACE POWER REACTORS; STIRLING ENGINES; GAS BEARINGS; HEAT RESISTANT ALLOYS; PRESSURE VESSELS; REFRA...
Publisher description

This thesis involves the fusion of two technologies, Stirling engines and additivemanufacturing. The project began by building a Stirling engine primarily out of 3D printed parts. Methods to measure the power output were designed and built with a combination of 3D printed and off the shelf parts. The Stirling engine was tested to see if there was a correlation to analysis results, and a regenerator was installed to determine the effect on performance for this relatively low temperature engine. Finally, variations in test operation and the use of heat sinks were used to find a combination that will allow the unit to run more reliably.One challenge of the 3D printed parts was the durability when subjected to heat and assembly loads, especially over multiple rebuilds. However, the convenience of 3Dprinting made it possible to print replacement parts easily. New designs and assemblies were also created as a part of the effort to develop a power measurement system.Power output was measured and corresponded to analysis predictions. Testing was conducted with a hot plate temperature of 349K (168 F) and a cold plate temperature of 308K (94 F), which corresponds to a Temperature Ratio of 1.13. Rate of rotation was 150 RPM, or 2.5 Hz. The net power output was measured to be 3.1mW. Adding that to the losses attributed to engine friction resulted in a gross power output of 17mW, which was close to the analysis prediction of 15mW. Regenerator testing showed that using a regenerator, on average, doubled the speed of rotation at the same temperature ratio. However, the regenerator was detrimental to long term operation because without active cooling, the cold plate was unable to dissipate the heat efficiently enough. Increasing the cold side heat transfer to ambient would be essential in increasing reliability. The addition of heatsinks to the cold side was tested to determine the effectiveness, with positive results. The heatsinks that were used in testing were also analyzed, and it was determined that the spacing was too narrow for optimum performance. For future designs, custom heatsinks could be used that maximize the natural convection of the cold side, or a method developed to provide active cooling.

The Ringbom engine, an elegant simplification of the Stirling, is increasingly emerging as a viable, multipurpose engine. Despite its technical elegance, high-speed stable operation capabilities, and potential as an environment-friendly energy source, the advantages manifest in Ringbom design have been slowly realized, due in large to part to its often enigmatic operating regime. This book presents for the first time a clear, tractable mathematical model of the dynamic properties of the Ringbom, resulting in a theorem that offers a complete characterization of the stable operating mode of the engine. The author here details the research leading to the development of the Ringbom and illustrates theoretical results, engine characteristics, and design principles using data from actual Ringbom engines. Throughout the book, the author emphasizes an understanding of Ringbom engine properties through closed form mathematical analysis and lucidly details how his mathematical derivations apply to real engines. Extensive descriptions of the engine hardware are included to aid those interested in their construction. Mechanical, electrical, and chemical engineers concerned with power systems, power generation, energy conservation, solar energy, and low-temperature physics will find this monograph a comprehensive and technically rich introduction to Stirling Ringbom engine technology.

This book comprises selected peer-reviewed proceedings of the International Conference on Applications of Fluid Dynamics (ICAFD 2018) organized by the School of Advanced Sciences, Vellore Institute of Technology, India, in association with the University of Botswana and the Society for Industrial and Applied Mathematics (SIAM), USA. With an aim to identify the existing challenges in the area of applied mathematics and mechanics, the book emphasizes the importance of establishing new methods and algorithms to address these challenges. The topics covered include diverse applications of fluid dynamics in aerospace dynamics and propulsion, atmospheric sciences, compressible flow, environmental fluid dynamics, control structures, viscoelasticity and mechanics of composites. Given the contents, the book is a useful resource for students, researchers as well as practitioners.

The original Air Engines (also known as a heat, hot air, caloric, or Stirling engines), predated the modern internal combustion engine. This early engine design always had great potential for high efficiency/low emission power generation. However, the primary obstacle to its practical use in the past has been the lack of sufficiently heat resistant materials. This obstacle has now been eliminated due to the higher strength of modern materials and alloys. Several companies in the U.S. and abroad are successfully marketing new machines based on the Air Engine concept. Allan Organ and Theodor Finkelstein are two of the most respected researchers in the field of Air Engines. Finkelstein is considered a pioneer of Stirling cycle simulation. The historical portion of the book is based on four famous articles he published in 1959. The rest of the chapters assess the development of the air engine and put it in the modern context, as well as investigate its future potential and applications. The audience for this book includes mechanical engineers working in power related industries, as well as researchers, academics, and advanced students concerned with recent developments in power generation. Co-published by Professional Engineering Publishing, UK, and ASME Press.