Chinese-Pakistani Dual-Use Related Research
Annotated Open Source Bibliography

By Mark Gorwitz

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Cyber Related Research:

PHDS: IP Prefix Hijack Detection System

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Abstract- Border Gateway Protocol (BGP) is the routing protocol for routing information between autonomous systems (AS) on the Internet. Back in 1989, BGP was not developed with a security perspective. Therefore, there are many security concerns regarding BGP, and it is highly vulnerable to malicious attacks. Due to rapid development in Internet technology, the Internet is filled with malicious users. It is not challenging to hijack someone's address space and use it for malicious activities such as denial-of-service attacks (DoS attacks) and spamming. Our aim behind this research work is to figure out and discuss all the techniques regarding BGP prefix hijacking and design a system that can be used to detect IP prefix hijacking attacks and facilitates mitigation. In this type of hijack attack, to avoid Multiple Origin AS (MOAS) conflicts, the attacker announces a hijacked prefix with AS number belongs to victim AS; this creates the illusion that BGP speaker has a direct connection with victim AS. To accurately detect IP prefix hijack attacks, we design a system called Prefix Hijack Detection System (PHDS). To test our system, we have collected all the Autonomous Systems (ASes) of Pakistan and their prefixes using RIPEstat API. PHDS collect BGP updates for every prefix using RIPEstat API. To monitor all 5,845 prefixes of Pakistan, we have collected 3.35 million BGP updates; all this data is collected from November 03, 2018, to November 20, 2018. We have monitored these prefixes through PHDS and found our system correctly detecting all types of IP prefix hijacks. Therefore, this system is useful for early detection of IP prefix hijack attacks. PHDS detects 47,223 malicious updates out of 3.35 million BGP updates. PHDS detected 983 unique IP prefix hijack attacks from 47,223 malicious updates. Hijack, a prefix, and it's AS is the most common type of attack; PHDS detected 983 prefix hijack attacks, and out of these, 898 are hijacked a prefix, and its AS.

A State Optimization Model Based on Kalman Filtering and Robust Estimation Theory for Fusion of Multi-Source Information in Highly Non-linear Systems

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Abstract

Consistent state estimation is a vital requirement in numerous real life applications from localization to multi-source information fusion. The Kalman filter and its variants have been successfully used for solving state estimation problems. Kalman filtering-based estimators are dependent upon system model assumptions. A deviation from defined assumptions may lead to divergence or failure of the system. In this work, we propose a Kalman filtering-based robust state estimation model using statistical estimation theory. Its primary intention is for multiple source information fusion, although it is applicable to most non-linear systems. First, we propose a robust state prediction model to maintain state constancy over time. Secondly, we derive an error covariance estimation model to accept deviations in the system error assumptions. Afterward, an optimal state is attained in an iterative process using system observations. A modified robust MM estimation model is executed within every iteration to minimize the impact of outlying observation and approximation errors by reducing their weights. For systems having a large number of observations, a subsampling process is introduced to intensify the optimized solution redundancy. Performance is evaluated for numerical simulation and real multi sensor data. Results show high precision and robustness of proposed scheme in state estimation.

Detached Eddy Simulations an Economical Tool for CFD

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Abstract— Flow field around high speed vehicles is very complex and difficult to simulate. The boundary layers are squeezed between shock layer and body surface. Resolution of boundary layer, shock wave and turbulent regions where the flow field has high values is difficult to capture. DNS and Large eddy simulation (LES) are very good CFD techniques but these are computationally expensive. The latter allows to generate useful solutions to transient flows, while still maintaining computationally realistic problems. Detached eddy simulation (DES) is a modification of a RANS model in which the model switches to a subgrid scale formulation in regions fine enough for LES calculations. Regions near solid body boundaries and where the turbulent length scale is less than the maximum grid dimension are assigned the RANS mode of solution. As the turbulent length scale exceeds the grid dimension, these regions are solved using the LES mode. Therefore the grid resolution is not as demanding as pure LES, thereby considerably cutting down the cost of the computation. In this research study supersonic flow is simulated at Mach 4 and different angle of attacks to calculate aerodynamics characteristics. The results are compared with experimental as well as turbulence model (K-ω SST Model). The

results achieved with DES simulation have very good resolution as well as have reasonable agreement with experimental and available data at low cost.

Comparative Study of Limiters for Harten-Yee TVD Scheme

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Abstract— The maturity of shock-capturing finite difference methods for hyperbolic conservation laws has been a rapidly growing area for the last three decade. The construction of efficient high order low dissipation numerical methods for nonlinear hyperbolic conservation laws has been the subject of much research recently. The objective of the present work is to discuss the applicability and limitation of different limiters for Harten-Yee TVD Scheme. Hypersonic flow over a flat plate and compression corner are solved for comparative study. In all test cases, the flow is laminar, hypersonic, and the conditions are such that the perfect gas assumption is sufficient to describe the thermodynamics. Comparison is made between numerical and available experimental results. Steady-state numerical solution for the unsteady Navier-Stokes equation of finite-difference form is obtained. Roe's approximate average state is used to calculate eigenvalues and eigenvector matrix.

Enhanced Privacy and Authentication: An Efficient and Secure Anonymous Communication for Location Based Service Using Asymmetric Cryptography Scheme

Wireless Pers Commun DOI 10.1007/s11277-015-2699-1

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Abstract: Past few years, the mobile technology and location based services have experienced a great increment in number of its users. The privacy issues related to these services are becoming main concerns because of the leakage of users' private information and contents. To prevent revelation of private information, many researchers have proposed several secure and authentication schemes which apply various technologies to provide integral security properties, such as symmetric encryption, digital signature, timestamp, etc. Unfortunately, some of these schemes still exhibit security and efficiency issues. In this research paper, we proposed an efficient and secure anonymous communication for location based service using asymmetric cryptography scheme over the wireless system was attempted missing some system detail. We also proposed the prevent user private information and secure communication by asymmetric cryptography scheme. We solved the wireless communication problem in A3 algorithm such as eavesdropping and this problem solved by asymmetric cryptography scheme because of its

robustness against this type of attack by providing mutual authentication make the system more secure. Finally, performance and cost analysis show our scheme is more suitable for lowpower and resource limited wireless system and thus availability for real implementation. According to our security analysis and performance, we can prove that our proposed.

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Underwater Research:

Structure design and workspace calculation of 6-DOF underwater manipulator

Asghar Khan; Wang Li Quan

Abstract:
This paper describes the structure design of a 6-DOF (Degree of Freedom) underwater robotic manipulator arm and the analysis of its workspace. Robotic arm very closely resemble human hand and its design is based on the principle of human hand. The structure of the manipulator arm consists of shoulder, elbow and wrist. The robotic manipulator arm works underwater more safely and for longer time as it does not breathe like human. The arm is designed for underwater applications of pick and place, inspection and welding and other related work. The manipulator is 6-DOF serial robotic arm, like other common industrial robotic manipulator. It has 6 joints, which are all of revolute type. The manipulator structure is designed such that all links are connected in series by DC motor-actuated joints from base to an end-effector. The material of the links and joint shell is selected water resistant and all the joints are made waterproof by using both static and dynamic sealing. The motors and reducers are selected for each joint on the basis of static moment balance approach. The structure of the manipulator arm is modeled in pro-e modeling software. The workspace of the manipulator is calculated using both the MATLAB Robotics toolbox and graphical method. The toolbox gives the 3-D workspace while the graphical method gives the 2-D workspace in horizontal and vertical plane.

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Formation control of impulsive networked autonomous underwater vehicles under fixed and switching topologies

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Keywords: Autonomous underwater vehicle (AUV) Formation control Fixed and switching topologies Impulsive networked abstract In this paper, a novel impulsive networked scheme is investigated to solve the formation control problem of a multi-autonomous underwater vehicle (multi-AUV) system. More specifically, instead of requiring continuous-time communication, in this scheme, information exchanges among the AUVs are conducted via impulse time sequences, which is more practical in the unreliable and narrow banded underwater acoustic communication

environment. In particular, the proposed scheme has significant advantages in energy conservation and improved robustness and can be widely applied in many other types of multi-agent systems. Sufficient conditions are derived to guarantee that the desired formation of the multiple AUVs can be achieved under either fixed or switching communication topologies. Finally, two numerical examples are provided to demonstrate the effectiveness of the theoretical results.

RBPF-MSIS: Toward Rao-Blackwellized Particle Filter SLAM for Autonomous Underwater Vehicle With Slow Mechanical Scanning Imaging Sonar

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Abstract—Simultaneous localization and mapping (SLAM) has the potential to play a fundamental and significant role in achieving full autonomy for autonomous underwater vehicles (AUV). This article proposes a Rao-Blackwellized particle filter (RBPF) SLAM algorithm for an AUV equipped with a mechanically scanning imaging sonar (MSIS) that has a very slow scanning frequency. To tackle the issues of scan distortion and sonar data sparseness caused by the slow-sampling MSIS, the core of the algorithm is a carefully designed sliding window-based scan forming module. Then the formed scans are fed into the modified RBPF to build a consistent grid-based map thus localizing the AUV accurately. Extensive simulation and experiments are carried out to verify the proposed algorithm. The results show that the proposed algorithm outperforms existing ones in terms of the level of map consistency with the environment as well as the accuracy of pose estimation.

Three-dimensional Computational Fluid Dynamics Based Design of Hull and Propeller of an Underwater Vehicle

Proceedings of 2018 International Bhurban Conference on Applied Science and technology, Islamabad, Pakistan, January 9-13, 2018

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Abstract—Underwater Vehicles are now used widely for mining, marine research, and military surveillance etc. Design of the vehicle is of paramount importance as efficiency of the mechanical equipment is one of the important areas of research these days. A little increase in efficiency can help saving a large amount of fuel, and consequently, decreasing amount of money required to be spent and weight of vehicle. Design study of the vehicle may be carried out by performing a parametric study related to the hydrodynamics of the vehicle. Considering the geometric and kinematic characteristics of the blades and the hull, this study aims to figure out a configuration for greater hydrodynamic efficiency of the vehicle. Since real-time experimental equipment is expensive, we adopted a computational approach. For the present study, simulations for incompressible viscous flow over the underwater vehicle through a finite-volume method based industrial flow solver-ANSYS Fluent were employed. During the simulations, we swept over a parametric space consisting of hull shape, aspect ratio of the vehicle, and Reynold's number.

A review of different designs and control models of remotely operated underwater vehicle

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Abstract This article reviews remotely operated underwater vehicle (ROUV) and its different types focusing on the control systems. This study offers a brief introduction of unmanned underwater vehicle (UUV) together with ROUV. Underwater robots are designed to work as an alternative to humans because of a difficult and hazardous underwater environment. The applications and demand of marine robots are increasing with the passage of time. There are several research articles and publications available on these topics but, a complete review of old and recent research about this technology is still hard to find. This article also assesses some recently published research papers on underwater systems. It presents the comparison of different control systems and designs of underwater vehicles. There have been major developments in marine technology depending on the needs, applications and cost of different missions. Scientists design many remotely operated vehicles based on the educational or industrial purposes. This article is presented in order to help and assist the future researchers as a massive review of the field of remotely operated underwater vehicles and their possible future developments are presented.

An adaptive sliding mode actuator fault tolerant control scheme for octorotor system

International System of Advanced Robotic Systems, March-April 2019, pp1-12

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Abstract: In this article, an adaptive sliding mode control is used in the framework of fault tolerant control to mitigate the effects of actuator faults without requiring the actuator health information. Since unmanned aerial vehicles are being used in multiple fields such as military, surveillance, media, agriculture, communication and trading sector, therefore it is of vital importance to overcome the effects of actuator faults that can decline system performance and can even lead to some serious accidents. The proposed adaptive sliding mode control approach can handle actuator faults directly without requiring any faults information and adaptively adjusts controller gains to maintain acceptable level of performance. To validate the effectiveness of the proposed adaptive fault tolerant control scheme, it has been tested in simulations using non-linear Benchmark model of Octorotor system and its performance is compared with the optimal LQR control approach.

Impact of Transmission Power Control Mechanism in Underwater Wireless Sensor Networks

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Abstract: Underwater Wireless Sensor Networks (UWSNs) face challenges regarding high propagation delay, limited bandwidth, 3D topology and excessive energy consumptions. In this paper, we propose transmission power control mechanism for Underwater Wireless Sensor Networks (UWSNs). We experimentally investigate the impact of transmission power and propose a control mechanism to enhance the performance of underwater wireless sensor network. We consider a homogenous network in which each sensor node has four different power levels as a concentric circle. In this proposed mechanism, source nodes will adjust its transmission power according to the location of destination node. This paper aims to provide a mechanism which is incorporated in SEEC. This study also outlines the mathematical modeling for proposed idea. Moreover, we have compared results of our scheme with previous implemented schemes. The statistical significance of this work was analyzed in MATLAB. Marked observations to emerge from our results include an improvement in lifetime, increased throughput, higher residual energy, increment in alive nodes and balanced energy consumption. In our view, these results strengthen the validity of our proposed power control mechanism. We observe a significant increase in received packets because maximum nodes are alive till 1500 rounds which provides maximum communication and less chance of creating void holes.

Performance Analysis of Selective Mapping in Underwater Acoustic Orthogonal Frequency Division Multiplexing Communication System

Engineering, Technology and Applied Science Research, 2021, Vol. 11(1), pp6696-6702

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Abstract-Under-Water Acoustic (UWA) communication networks are commonly formed by associating various independent UWA vehicles and transceivers connected to the bottom of the sea with battery-operated power modems. Orthogonal Frequency Division Multiplexing (OFDM) is one of the most vital innovations for UWA communications, having improved data rates and the ability to transform fading channels into flat fading. Moreover, OFDM is more robust on InterSymbol and Inter-Carrier Interferences (ISI and ICI respectively). However, OFDM technology suffers from a high Peak to Average Power Ratio (PAPR), resulting in nonlinear distortions and higher Bit Error Rates (BERs). Saving power of battery deployed modems is an important necessity for sustainable underwater communications. This paper studies PAPR in UWA OFDM communications, employing Selective Mapping (SLM) as a tool to mitigate PAPR. The proposed SLM with the oversampling factor method proves to be less complex and more efficient. Simulation results indicate that SLM is a promising PAPR reduction method for UWA OFDM communications reducing BER.

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Numerical investigation on the water entry impact characteristics of autonomous underwater vehicles

Ahmad Zamir Chaudhry; Yao Shi; Guang Pan; Abdul Shakoor; Syed Shah Khalid

Abstract:
Water entry of autonomous underwater vehicles (AUVs) is an unsteady and complex process accompanied by a huge hydrodynamic impact force which consequently affects the structure globally and locally. Therefore, precise modeling of this phenomenon is indispensable for the structure design of the vehicle. In this article, numerical model employing an Arbitrary-Lagrangian Eulerian (ALE) formulation is used to study the water entry impact of AUV. A penalty coupling algorithm will be employed which allows the interaction between the solid and the fluids. The feasibility and precision of the numerical technique is validated by the experimental data of the water entry of a decelerating object. After validation, the proposed numerical method is employed to examine the hydrodynamic behavior of AUV water entry under various launch parameters at the initial stage of impact. Numerical results from ALE method are also compared with smooth particle hydrodynamics (SPH) method. This reveals that ALE method can accurately simulate large deformation problems with less computational cost. The analysis results indicate that the time period at which the impact acceleration reaches its maximum value decreases as the launch velocity of the AUV increases. Axial and radial impact loads are calculated at various launch angles for fixed impact velocity of the vehicle. It is shown

that oblique water entry of AUV is more sensitive to the radial impact load. It is concluded that water entry angle and launch velocity are the crucial parameters greatly influencing the impact characteristics of the AUV. Quantitative comparison between numerical and experimental data proves that the proposed numerical algorithm can reliably be used for water entry impact problems at high velocities.

2020 17th International Bhurban Conference on Applied Sciences and Technology (IBCAST)

Numerical Computation of Wave Forces on Blended Winged-Body Underwater Glider using Panel Method

Xiaoxu Du; Naveed Ali

Abstract:
The long endurance, energy efficiency and nature of locomotion have proved underwater glider (UG) to be the most suitable choice for long-term ocean environmental monitoring and detection of marine resources. Being buoyancy driven slow speed underwater vehicle, external environmental disturbance such as waves significantly affect the operational autonomy and stability of UG along the designed glide path. The assessment of these external disturbances on UG is significantly important to design better control systems and vehicle designs. Accurate wave predictions methods are needed to improve the reliability and efficiency of UG. This study develops a formulation based on panel method for numerical computation of wave force on submerged UG operating along the glide path. The proposed method is implemented using ANSYS Hydrodynamic Diffraction (HD) and Hydrodynamic Time Response (HTR) modules which require discretization of UG surface into panels, defining mass properties and generating the desired environmental sea conditions. Numerous simulations are performed considering linearized Airy head sea waves. Deep sea water conditions with infinite length and width of water column are considered so the interference effects due to bottom and vertical boundaries can be neglected. The numerical simulations are carried out in frequency as well as time domains to calculate wave loadings for different UG submergence depths and pitch angles; and different wave amplitudes and frequencies. The surge and heave wave forces; and pitch wave moment are found to be most dominant in head sea condition. Using MATLAB curve fitting tool, the analytical formulas for dominant wave forces and moment on the UG is obtained in terms of wave and UG parameters based on the numerical simulation results. The derived analytical wave force formulations coupled with motion dynamics and hydrodynamics model provide an efficient tool to analyze UG dynamics in time domain and evaluate the influence of different wave parameters on the dynamic characteristics and navigation of UG.

2021 International Bhurban Conference on Applied Sciences and Technologies (IBCAST)

CFD based investigation of the unsteady hydrodynamic coefficients of 3-D fins in viscous flow

- Zulfiqar Nazir,
- Yu-min Su &
- Zhao-li Wang

Journal of Marine Science and Application, volume 9, pages250–255 (2010)

Abstract

The motion of the fins and control surfaces of underwater vehicles in a fluid is an interesting and challenging research subject. Typically the effect of fin oscillations on the fluid flow around such a body is highly unsteady, generating vortices and requiring detailed analysis of fluid-structure interactions. An understanding of the complexities of such flows is of interest to engineers developing vehicles capable of high dynamic performance in their propulsion and maneuvering. In the present study, a CFD based RANS simulation of a 3-D fin body moving in a viscous fluid was developed. It investigated hydrodynamic performance by evaluating the hydrodynamic coefficients (lift, drag and moment) at two different oscillating frequencies. A parametric analysis of the factors that affect the hydrodynamic performance of the fin body was done, along with a comparison of results from experiments. The results of the simulation were found in close agreement with experimental results and this validated the simulation as an effective tool for evaluation of the unsteady hydrodynamic coefficients of 3-D fins. This work can be further be used for analysis of the stability and maneuverability of fin actuated underwater vehicles.

Controlling and Stabilizing the Position of Remotely Operated Underwater Vehicle Equipped with a Gripper

- Zain Anwar Ali,
- Xinde Li &
- Muhammad Ahsan Tanveer

Wireless Personal Communications, volume 116, pages1107–1122 (2021)

Abstract

Gripper mounted remotely operated underwater vehicle (ROUV) delivers more attractive and flexible solution to grasp the wanted objects inside the deep water. The main aim of this research is to stabilize and control the position of fully actuated (ROUV) equipped with a gripper. The nonlinear model based observer along with proportional, integral and derivative (PID) controller designed to stabilize and control the position of fully actuated ROUV along with the motion of attached gripper in it. However, the PID controller utilize to control the altitude of the vehicle and nonlinear-based observer with PID controller designed to control and stabilize the attitude of ROUV. The designed control algorithm applied on the model of six degrees of freedom (6 DOF) ROUV attached with a gripper that has (2 DOF) that makes total (8 DOF) to control. The hydrodynamic behavior, instability that produces by the arm that is the main reason to design

two different controllers to control and stabilize the altitude and attitude of ROUV. Hence, it observes that designed control scheme has better stability and better transient behavior.

Formation control of impulsive networked autonomous underwater vehicles under fixed and switching topologies

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Keywords: Autonomous underwater vehicle (AUV) Formation control Fixed and switching topologies Impulsive networked abstract In this paper, a novel impulsive networked scheme is investigated to solve the formation control problem of a multi-autonomous underwater vehicle (multi-AUV) system. More specifically, instead of requiring continuous-time communication, in this scheme, information exchanges among the AUVs are conducted via impulse time sequences, which is more practical in the unreliable and narrow banded underwater acoustic communication environment. In particular, the proposed scheme has significant advantages in energy conservation and improved robustness and can be widely applied in many other types of multi-agent systems. Sufficient conditions are derived to guarantee that the desired formation of the multiple AUVs can be achieved under either fixed or switching communication topologies. Finally, two numerical examples are provided to demonstrate the effectiveness of the theoretical results.

RBPF-MSIS: Toward Rao-Blackwellized Particle Filter SLAM for Autonomous Underwater Vehicle With Slow Mechanical Scanning Imaging Sonar

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Abstract—Simultaneous localization and mapping (SLAM) has the potential to play a fundamental and significant role in achieving full autonomy for autonomous underwater vehicles

(AUV). This article proposes a Rao-Blackwellized particle filter (RBPF) SLAM algorithm for an AUV equipped with a mechanically scanning imaging sonar (MSIS) that has a very slow scanning frequency. To tackle the issues of scan distortion and sonar data sparseness caused by the slow-sampling MSIS, the core of the algorithm is a carefully designed sliding window-based scan forming module. Then the formed scans are fed into the modified RBPF to build a consistent grid-based map thus localizing the AUV accurately. Extensive simulation and experiments are carried out to verify the proposed algorithm. The results show that the proposed algorithm outperforms existing ones in terms of the level of map consistency with the environment as well as the accuracy of pose estimation.

Three-dimensional Computational Fluid Dynamics Based Design of Hull and Propeller of an Underwater Vehicle

Proceedings of 2018 International Bhurban Conference on Applied Science and technology, Islamabad, Pakistan, January 9-13, 2018

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Abstract—Underwater Vehicles are now used widely for mining, marine research, and military surveillance etc. Design of the vehicle is of paramount importance as efficiency of the mechanical equipment is one of the important areas of research these days. A little increase in efficiency can help saving a large amount of fuel, and consequently, decreasing amount of money required to be spent and weight of vehicle. Design study of the vehicle may be carried out by performing a parametric study related to the hydrodynamics of the vehicle. Considering the geometric and kinematic characteristics of the blades and the hull, this study aims to figure out a configuration for greater hydrodynamic efficiency of the vehicle. Since real-time experimental equipment is expensive, we adopted a computational approach. For the present study, simulations for incompressible viscous flow over the underwater vehicle through a finite-volume method based industrial flow solver-ANSYS Fluent were employed. During the simulations, we swept over a parametric space consisting of hull shape, aspect ratio of the vehicle, and Reynold's number.

Formation control of impulsive networked autonomous underwater vehicles under fixed and switching topologies

Neurocomputing, 2015, Vol. 147, pp291-298

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Abstract—Underwater Vehicles are now used widely for mining, marine research, and military surveillance etc. Design of the vehicle is of paramount importance as efficiency of the mechanical equipment is one of the important areas of research these days. A little increase in efficiency can help saving a large amount of fuel, and consequently, decreasing amount of money required to be spent and weight of vehicle. Design study of the vehicle may be carried out by performing a parametric study related to the hydrodynamics of the vehicle. Considering the geometric and kinematic characteristics of the blades and the hull, this study aims to figure out a configuration for greater hydrodynamic efficiency of the vehicle. Since real-time experimental equipment is expensive, we adopted a computational approach. For the present study, simulations for incompressible viscous flow over the underwater vehicle through a finite-volume method based industrial flow solver-ANSYS Fluent were employed. During the simulations, we swept over a parametric space consisting of hull shape, aspect ratio of the vehicle, and Reynold's number.

A review of different designs and control models of remotely operated underwater vehicle

Measurement and Control, 2020, Vol. 53(9-10), pp1561-1570

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Abstract This article reviews remotely operated underwater vehicle (ROUV) and its different types focusing on the control systems. This study offers a brief introduction of unmanned underwater vehicle (UUV) together with ROUV. Underwater robots are designed to work as an alternative to humans because of a difficult and hazardous underwater environment. The applications and demand of marine robots are increasing with the passage of time. There are several research articles and publications available on these topics but, a complete review of old and recent research about this technology is still hard to find. This article also assesses some recently published research papers on underwater systems. It presents the comparison of different control systems and designs of underwater vehicles. There have been major developments in marine technology depending on the needs, applications and cost of different missions. Scientists design many remotely operated vehicles based on the educational or industrial purposes. This article is presented in order to help and assist the future researchers as a

massive review of the field of remotely operated underwater vehicles and their possible future developments are presented.

Generalized pseudo Bayesian algorithms for tracking of multiple model underwater maneuvering target

Applied Acoustics, 2020, Vol. 166, 107345

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Abstract: The strength of Generalized Pseudo Bayesian (GPB) algorithms is exploited in the presented study to enhance the target tracking precision, effective model approximation and rapid convergence of multimodel maneuvering object tracking. The GPB methods are considered to be suitable for approximating systems whose dynamics follow discrete-time and fixed state Markov process. Underwater maneuvering target tracking problems are usually solved with nonlinear Bayesian algorithms, in which kinetics of object are associated with passive bearings using state-space modeling. Here accuracy and convergence of GPB methods based on Interacting Multiple Model Extended Kalman Filter (IMMEKF), Interacting Multiple Model Extended Kalman Smoother (IMMEKS), Interacting Multiple Model Unscented Kalman Filter (IMMUKF) and Interacting Multiple Model Unscented Kalman Smoother (IMMUKS) are efficiently analyzed for tracking of multimodel maneuvering target in complex ocean environment. Application of these algorithms is systematically presented for estimating the real-time state of a maneuvering object that follows a coordinated turn trajectory. Performance analysis of IMM Kalman filters and smoothers is done with variations in the standard deviation of white Gaussian measurement noise by following Bearings Only Tracking (BOT) phenomena. Least Mean Square Error (MSE) between approximated and the real position of maneuvering target in rectangular coordinates is calculated for analyzing the performance of filtering and smoothing techniques. Simulation results of the Monte Carlo runs validate the effectiveness of IMMEKS and IMMUKS over IMMEKF and IMMUKF for scenario of given framework.

UAV Research:

Attitude heading reference algorithm based on transformed cubature Kalman filter

Measurement and Control, 2020, Vol. 53(7-8), pp1446-1453

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Abstract: Stable and accurate attitude estimation is the key to the autonomous control of unmanned aerial vehicle. The Attitude Heading Reference System using micro-electro-mechanical system inertial measurement unit and magnetic sensor as measurement sensors is an indispensable system for attitude estimation of the unmanned aerial vehicle. Aiming at the

problem of low precision of the Attitude Heading Reference System caused by the nonlinear attitude model of the micro unmanned aerial vehicle, an attitude heading reference algorithm based on cubature Kalman filter is proposed. Aiming at the nonlocal sampling problem of cubature Kalman filter, the transformed cubature Kalman filter using orthogonal transformation of the sampling point is presented. Meanwhile, an adaptive estimation algorithm of motion acceleration using Kalman filter is proposed, which realizes the online estimation of motion acceleration. The car-based tests show that the algorithm proposed in this paper can accurately estimate the carrier's motion attitude and motion acceleration without global positioning system. The accuracy of acceleration reaches 0.2 m/s2 , and the accuracy of attitude reaches 1

Modeling and Backstepping-based Nonlinear Control Strategy for a 6 DOF Quadrotor Helicopter

Chinese Journal of Aeronautics, Volume 21, Issue 3, June 2008, Pages 261-268

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Abstract

In this article, a nonlinear model of an underactuated six degrees of freedom (6 DOF) quadrotor helicopter is derived on the basis of the Newton-Euler formalism. The derivation comprises determining equations of the motion of the quadrotor in three dimensions and approximating the actuation forces through the modeling of aerodynamic coefficients and electric motor dynamics. The derived model composed of translational and rotational subsystems is dynamically unstable, so a sequential nonlinear control strategy is used. The control strategy includes feedback linearization coupled with a PD controller for the translational subsystem and a backstepping-based PID nonlinear controller for the rotational subsystem of the quadrotor. The performances of the nonlinear control method are evaluated by nonlinear simulation and the results demonstrate the effectiveness of the proposed control strategy for the quadrotor helicopter in quasi-stationary flights.

Foundation item: Higher Education Commission, Government of Pakistan (1-3/PM-OVER/China/2005)

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Vitae

Biography:
Ashfaq Ahmad Mian Born in 1973, he received B.S. from University of Engineering and Technology and M.S. from Quaid-e-Azam University, Pakistan, in 1997 and 2000 respectively. Since then, he joined the R&D organization, NESCOM. Now he is a Ph.D. candidate in Nanjing University of Aeronautics and Astronautics. His main research interests are autopilot design, nonlinear control of MIMO systems, controller fragility and robust control.

Vibration isolation concepts for non-cubic Stewart Platform using modal control

Proceedings of 2014 11th International Bhurban Conference on Applied Sciences & Technology (IBCAST) Islamabad, Pakistan, 14th - 18th January, 2014

Hussain Abbas ; Sch. of Astronaut., Beihang Univ., Beijing, China ; Huang Hai

Abstract: Literature falls much short in presenting simplified dynamic models for non-cubic Stewart Platforms to aid in its initial design. This paper uses geometric parameters of the non-cubic Stewart Platforms to determine its dynamic equations for base excitations for individual controllers. These subsystems are then decoupled to give individual modal equations, to give the advantage of controlling each mode independently. Considerable vibration isolation was observed when compared with passive vibration control.

Material Science Research:

Carbon Composites:

Residual compressive and thermophysical properties of 4D carbon/carbon composites after repeated ablation under oxyacetylene flame of 3000 °C

Transactions of the Nonferrous Metal Society of China, 2013, Vol. 23, pp1661-1667

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Abstract: The performance of carbon-carbon (C/C) composite’s reusable parts regarding the extent of erosion, and residual mechanical and thermophysical properties in high temperature applications was studied. C/C composites were fabricated with fourdirectional preform architecture. The composites were repeatedly ablated using oxyacetylene flame of about 3000 °C for 30 s each time. The results show that the ablation rate of the composite is linearly proportional to the ablation time; a single step ablation shows a higher ablation rate as compared to the ablation carried out in steps, keeping the total ablation time the same. The surface roughness and exposure area of the specimen to the flame were found to significantly increase the ablation rate. The compressive strength, thermal conductivity and coefficient of thermal expansion (CTE) of the composite were found to decrease after every ablation test, whereas the specific heat capacity of the composite remained unchanged.

Preparation and characterization of carbon foam derived from pitch and phenolic resin using a soft templating method

Journal of Analytical and Applied Pyrolysis, 2014, Vol. 110, pp229-234

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Ab s t r a c t Carbon foam has been developed by soft templating method with phenolic resin and coal tar pitch as matrix precursor and polyurethane (PU) foam as an organic sacrificial template. Micron sized powdered pitch was mixed well in a diluted resin and the PU foam was soaked in it. The impregnated foam was dried at 70 ◦C for 6 h. This impregnation–stabilization (IS) process was repeated for four and six times. A slow curing cycle with hold steps at 80, 110, 140 and 2000 ◦C was used for the sample being pressed isostatically in a steel mold. Carbonization at 800 ◦C in a reduced and inert environment resulted in a geometric density of 0.48 and 0.60 g/cm3 for IS cycles of four and six respectively. The carbon foam was characterized by porosity calculations, thermogravimetric analysis, compressive strength and scanning electron microscopy. The developed carbon foam showed an open porosity of 63–67%, compressive strength of 13.3–19.5 MPa and pore size distribution of 10–500 m. An experimental setup was designed for the testing of carbon foam as a high temperature thermal insulation. The carbon foam specimen was heated to 975 ◦C on the one face and the other face was monitored. The experiment was repeated with a carbon-felt specimen and the insulation indices compared. The carbon foam showed a higher insulation index but lower insulation index due to higher density than that of the carbon felt.

Mechanical, structural and oxidation resistance enhancement of carbon foam by in situ grown SiC nanowires

Ceramics International, 2016, Vol. 42, pp4723-4733

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Received 30 October 2015; accepted 24 November 2015 Available online 10 December 2015

Abstract A method for processing carbon foams containing both silicon carbide (SiC) nanowires and bulk SiC and silicon nitride (Si3N4) phases has been developed by reaction of powder mixtures containing precursors for carbon, sacrificial template, silicon (Si), short carbon fibers (SCF) and activated carbon (AC). In situ growth of Si nanowires during pyrolysis of the foam at 1000 1C under N2 changed the foam's microstructure by covering the porous skeleton inside and out. In situ-grown SiC nanowires were found smoothly curved with diameters ranging around two main modes at 30 and 500 nm while their lengths were up to several tens of micrometers. SCF were found effectively mixed and well-bonded to pore walls. Following density, porosity and pore size distribution analyses, the heat-treated (HT) foam was densified using a chemical vapor infiltration (CVI) process. Thereafter, density increased from 0.62 to 1.30 g/cm3 while flexural strength increased from 29.3 to 49.1 MPa. The latter increase was attributed to the densification process as well as to low surface defects, presence of SCF and coating, by SiC nanowires, of the entire SiC matrix porous structure. The foam's oxidation resistance improved significantly from 58 to 84 wt% residual mass of the heat treated and densified sample. The growth mechanism of Si nanowires was supported by the vapor–liquid–solid mechanism developed under pyrolysis conditions of novolac and reducing environment of coal cover.

Characterization of latticed SiC nanowires containing coating for carbon foam using carbonization activated pack cementation process

Journal of Alloys and Compounds, 2016, Vol.682, pp695-705

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Abstract In order to improve the oxidation resistance of carbon foam, a silicon carbide (SiC) coating was prepared using carbonization-activated pack cementation method. Carbon foam was firstly carbonized partially at 500 C and then fully carbonized at 1600 C with pack powder containing activated carbon, silicon powder, and iron chloride. The as-obtained coating was characterized using scanning and transmission electron microscopies, X-ray diffraction, thermogravimetric analysis, oxidation thermal shock and coefficient of thermal expansion. The results showed that the coating was mainly composed of randomly distributed SiC nanowires extended inside the surface pores forming pinning effect. The growth mechanism involved dissolution of SiO and CO (vapors) in the Fi-Si melt (liquid) and precipitation of onedimensional SiC nanowires (solid). In non-isothermal oxidation, the coated carbon foam showed a mass loss of only 1.97%. The thermal shock results indicated that due to matching of thermal expansion coefficients, no cracks occurred on the surface after 15 cycles under temperature drop of 1475 C. Consequently, we expect that this new high temperature coating method, and the subsequent microstructure that it creates, can be widely applied to improve the thermal shock and oxidation resistance of carbon foam.

Gas and Liquid Routes-CMCs, C/C Composites -A review

Submitted to Prof. Yani Zhang School of Materials Science, NPU, Xi'an, China Prepared by Shameel Farhan PhD Student (Carbon foam core sandwich) student ID 2013410005

Protection against Oxidation – Carbon/Carbon Composites

Submitted to Prof. Fu Prof. Fu Prof. Fu Qian Gang Qian Gang Qian Gang C/C Composites Technology Research Centre, Department of Materials Prepared by Shameel Farhan Shameel Farhan PhD Student (Carbon foam core sandwich structures) Student ID 201310005

Novel thermal gradient chemical vapor infiltration process for carbon-carbon composites

New Carbon Materials, 2007, Vol. 22(3), pp247-252

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Abstract: Solid cylindrical carbon-carbon composites were processed using conventional thermal gradient chemical vapor infiltration. High thermal conductivity (55 W/m·°C) carbon fibers (48 k) were inserted in the center of a cylindrical low thermal conductivity (0.15 W/m·°C) needle punched carbon felt preform, to create a thermal gradient because of the difference in thermal conductivities. The hottest portion (900–1200 °C) was along the inserted carbon fibers, where the pyrolytic reaction of natural gas occurred. The densification radially moved outwards and ultimately a density of 1.778 g/cm3 was obtained after 67 h. The process parameters such as the electric power of the furnace, electrical resistance of the sample, densification time, and the

position of the deposition layer were studied. A densified sample having a volume fraction of carbon fibers of 10% was tested for ablation and erosion. The microstructure of the pyrolytic carbon matrix of the as-prepared sample was investigated by polarized light microscopy and scanning electron microscopy.

Effect of density and fibre orientation on the ablation behaviour of carbon-carbon composites

New Carbon Materials, 2010, Vol. 25(3), pp161-167

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Abstract: Five carbon-carbon composites were prepared with different fibre orientations in the preform and were densified by different methods. Their ablation behaviour was examined by an oxy-acetylene test and scanning electron microscopy. The densities of the composites were in the range of 1.77 to 1.85 g/cm3 . Fibres having an angle of 30° with the oxy-acetylene flame turned into a sharp wedge shape, whereas fibres parallel to the flame had a needle-like shape with diameter up to 3.5-4.5 μm after ablation. The needled fibres were easily attacked and ultimately became blunt. Partially filled macropores with sizes of 1.0-1.26 mm, needle pores, interfacial cracks and gaps in non-woven cloth were easily attacked by the flame, resulting in macroscopic ablation pits that decreased with increasing density of the composites. The needled fibres around pitch carbon layers were severely denuded due to their discontinuity with the pyrolytic carbon matrix. A high density (1.85 g/cm3) composite had an excellent ablation resistance.

Morphology, thermal response and anti-ablation performance of 3D-four directional pitch-based carbon/carbon composites

Corrosion Science, 2012, Vol. 61, pp134-142

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Abstract A high density 3D-four directional carbon/carbon composite was fabricated by hot isostatic pressure impregnation carbonisation using coal tar pitches. The thermo-oxidative, thermophysical and ablation properties of the composite were determined. Thermo-oxidative analysis shows that the carbon matrix is oxidised faster than the fibre. The composite shows a quasi-isotropic heat capacity and coefficient of thermal expansion, whereas its thermal conductivity depends on the fibre volume fraction in the test direction. The ablation in plasma is higher and more severe than in oxyacetylene, and the resistance of carbon fibres to ablation depends on their orientation relative to the flow of ablative gasses.

Residual compressive and thermophysical properties of 4D carbon/carbon composites after repeated ablation under oxyacetylene flame of 3000 °C

Transactions of Nonferrous Metals Society of China, Volume 23, Issue 6, June 2013, Pages 1661-1667

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[b] Department of Chemistry, Quaid-i-Azam University, Islamabad 45320, Pakistan

Abstract: The performance of carbon-carbon (C/C) composite's reusable parts regarding the extent of erosion, and residual mechanical and thermophysical properties in high temperature applications was studied. C/C composites were fabricated with four-directional preform architecture. The composites were repeatedly ablated using oxyacetylene flame of about 3000 °C for 30 s each time. The results show that the ablation rate of the composite is linearly proportional to the ablation time; a single step ablation shows a higher ablation rate as compared to the ablation carried out in steps, keeping the total ablation time the same. The surface roughness and exposure area of the specimen to the flame were found to significantly increase the ablation rate. The compressive strength, thermal conductivity and coefficient of thermal expansion (CTE) of the composite were found to decrease after every ablation test, whereas the specific heat capacity of the composite remained unchanged.

A new double layer oxidation resistant coating based on Er2SiO5/LaMgAl11O19 deposited on C/SiC composites by atmospheric plasma spraying

Surface and Coatings Technology, 2013, Vol. 219, pp101-108

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Abstract: A new coating with Er2SiO5 as inner layer and LaMgAl11O19 (LMA) as top layer was designed and deposited on C/SiC composites by atmospheric plasma spraying to improve the oxidation resistance of the substrate at high temperature. Microstructure, oxidation protection and failure mechanism of the Er2SiO5/LMA coating during dynamic thermal cycling (DTC) were investigated. The results showed that a good interfacial bonding between the substrate and the coating was present before and after DTC test. Weight loss for the sample coated on one-side was 4.5% after 11 cycles of heating for 85 min, and for the uncoated sample was as high as 20.6%. Failure mechanism of the coating resulted from the liquid sintering of the coating and the formation of bubbles between the substrate and the coating. ©

Flexural strength and thermal expansion of 4D carbon/carbon composites after flexural fatigue loading

New Carbon Materials, Volume 29, Issue 3, June 2014, Pages 169-175

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Abstract: A four directional carbon/carbon (4D C/C) composite was fabricated by first using liquid phase impregnation carbonization (LPIC), followed by hot isostatic pressure impregnation and carbonization (HIPIC) at 75 MPa, and finally high temperature treatment. The flexural properties and fracture behavior of the composite were investigated in the through-thickness direction under static and fatigue loading. The critical fatigue limit of the composite was 80% of the static flexural strength for one million loading cycles at 10 Hz. The failure mechanism of the composite under static flexural loading was dependent on the orientation of the carbon fibers in the tested specimen. Cyclic fatigue loading decreased the interfacial bonding strength and released the inherent stresses in the composite, which increased fiber pull-out, enhanced pseudo-ductility and increased the residual static flexural strength at the expense of a decrease in the flexural modulus. The fatigue loading increased the number of noncritical matrix cracks, increased interfacial debonding, and caused the fracture of filaments in the surviving fatigued C/C composite. These features of the fatigued composite internally accommodated expansion in long direction as the temperature was increased, which resulted in a decrease in its residual thermal expansion.

Directional thermophysical, ablative and compressive behavior of 3D carbon/carbon composites

Ceramics International, 2015, Vol. 41, pp9763-9769

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Abstract Three-dimensional carbon/carbon (C/C) composites with an apparent density higher than 1.84 g/cm3 were fabricated using multiple carbon fiber tows oriented in four directions and densified using a combined process. This consists of a pre-densification step using a thermal-gradient chemical vapor infiltration process followed by pitch impregnation/carbonization cycles carried out under high pressure. The samples were machined along X-, Y- and Z-axis of the preform architecture denoting the weakest to the strongest direction in the composite respectively. The Ydirectional sample showed the highest thermal diffusivity and the lowest CTE values. The directional ablative behavior was studied using plasma arc testing on a Huels type arc-heater. The Z-directional sample showed the lowest ablation and erosion rates while the other two showed a discrepancy in the linear and calculated erosion rates. To further investigate it, the samples after the test were analyzed in the heat-affected zone for a reduced density. Based on empirical correlation, a new term called “corrected linear ablation rate” has been formulated which also helped in the calculation of surface roughness after the ablation testing. Compressive tests were performed before and after plasma testing. After plasma testing, the compressive strength and modulus were almost the same except for the X-directional sample whose modulus reduced to 50%. The Xdirectional sample, being the weakest direction, showed a double shear

type failure, while the other two failed with end crushing, resulting from the different fiber architecture.

Variation of thermal expansion of carbon/carbon composites from 850 to 2500C

Ceramics International, 2014, Vol. 40, pp1273-1276

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Abstract Thermal expansion behaviors of carbon/carbon composites consisting of carbon fiber felts with high textured pyrolytic carbon matrix were investigated in a temperature range of 850–2500 1C. Coefficient of thermal expansion (CTE) of the composites without heat treatment decreased clearly in the two temperature ranges of 1300–1500 1C and 2100–2500 1C. Raman spectra and scanning electron microscope analyses of the composites heat treated at different temperatures showed that the reduction of structural defects in fibers, and the graphitization of carbon matrix were responsible for the decrease of CTE. Furthermore, fiber/matrix interfacial debonding and fiber pull-out during the CTE measurement occurred with the increase of heat treatment temperature up to 1500 1C, while at higher heat treatment temperature, circumferential cracks and layer bridging in the matrix were observed.

Flexural strength and thermal expansion of 4D carbon/carbon composites after flexural fatigue loading

New Carbon Materials, 2014, Vol. 29(3), pp169-175

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Abstract: A four directional carbon/carbon (4D C/C) composite was fabricated by first using liquid phase impregnation carbonization (LPIC), followed by hot isostatic pressure impregnation and carbonization (HIPIC) at 75 MPa, and finally high temperature treatment. The flexural properties and fracture behavior of the composite were investigated in the through-thickness direction under static and fatigue loading. The critical fatigue limit of the composite was 80% of the static flexural strength for one million loading cycles at 10 Hz. The failure mechanism of the composite under static flexural loading was dependent on the orientation of the carbon fibers in the tested specimen. Cyclic fatigue loading decreased the interfacial bonding strength and released the inherent stresses in the composite, which increased fiber pull-out, enhanced pseudo-ductility and increased the residual static flexural strength at the expense of a decrease in the flexural modulus. The fatigue loading increased the number of noncritical matrix cracks, increased interfacial debonding, and caused the fracture of filaments in the surviving fatigued C/C composite. These features of the fatigued composite internally accommodated expansion in long direction as the temperature was increased, which resulted in a decrease in its residual thermal expansion.

Sublimation and oxidation zone ablation behavior of carbon/carbon composites

Ceramics International, 2015, Vol. 41, pp13751-13758

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Abstract Three-dimensional carbon/carbon (C/C) composites comprising four reinforcement directions (4D) were fabricated using intermediate modulus carbon fibers and densified using a hybrid process. This consists of a pre-densification step using a thermal-gradient chemical vapor infiltration process followed by a high-pressure pitch impregnation and carbonization process. The specimens machined along Z-axis of the preform architecture were tested in an arc plasma heater for studying its ablation behavior at different temperatures. Regimes from ultra-high temperature (4750 K) sublimation to high-temperature (2467 K) oxidation zones were created by varying the mass flow rate of secondary air in the heater. The ablation rate showed a progressive increase as the environment changed from oxygen-lean sublimation to oxygen-rich oxidation conditions while the back-face temperature showed a similar temperature profile during the plasma exposure period. The thermal diffusivity value decreased with the rise in temperature till 1173 K and later on became fairly flat till 1523 K and onwards. In the compression test, 4750 K exposed specimen showed toughening in the plasma-affected zone and crushed with shear mode from the opposite face while the 2467 K exposed specimen showed end brushing in the plasma heat-affected face with a lower residual strength and Young's modulus.

Rheological properties, structural and thermal elucidation of coal-tar pitches used in the fabrication of multi-directional carbon-carbon composites

Materials Chemistry and Physics, 2020, Vol. 242, 122564

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ABSTRACT: Two types of coal-tar pitches varying by softening points and quinolone insoluble (QI) contents, used in the fabrication of carbon-carbon composites (C/C's), were studied using various techniques regarding their physical and chemical transformations during pyrolysis and graphitization. These pitches were highly graphitizable and were found the best suited for fabricating high-density multi-directional C/C's. Raman micro-spectroscopy (RMS) of the pitches showed a gradual decrease in the width and frequency of the G band as pyrolysis and graphitization proceeded, corresponding to the decrease of non-aromatic C–C bonds and increase in the ordered layered graphite network. The pitches showed non-Newtonian behavior because of the presence of QI particles, and their viscosity decreased with increasing shear rate and temperature. The decrease in viscosity with increasing shear rates was found constant at all measured temperatures. RMS and elemental analysis showed that structural transformation in the

pitch during pyrolysis took place most noticeably beyond 800C, resulting in an abrupt increase in the carbon/hydrogen ratio, due to the vanishing of mesophase structure and extension of the distorted carbon network. Sigmoidal curve fitting using the Boltzmann equation was found the best fit for the weight loss.

Metallurgical Research:

High strain rate deformation of explosion-welded Ti6Al4V/pure titanium

Defence technology, 2020, Vol. 16, pp678-688

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Article info Article history: Received 16 July 2019 Received in revised form 10 September 2019 Accepted 10 October 2019 Available online 14 October 2019 Keywords: Explosion welded Dynamic behaviour SHPB Titanium alloy

Abstract Multilayer materials are widely used in military, automobile and aerospace industries. In this paper, the response of an explosion-welded Ti6Al4V/pure titanium with a flat interface to dynamic loading is investigated. An SHPB apparatus is used. Then, the dynamic behaviour of a bimetal sample is explored with a DIC system coupled to the SHPB. Result indicates that in the bimetal sample pure titanium is deformed and failed before Ti6Al4V. The stress curve of the sample shows two different peaks in a striker velocity higher than the 18.3 m/s. When the incident wave encounters the interface of the Ti6Al4V/pure titanium sample, only a small fraction of the wave is reflected owing to similar impedance. Using the direct interpretation stress-strain curve is unreasonable in this case because of unhomogenised plastic deformation. The microstructure of the sample is investigated after loading. An adiabatic shear band is formed in the pure titanium side before failure, and the interface of the sample remains intact under different loading conditions. The FEM simulation result for the sample is in good agreement with experimental observations.

Experimental and numerical investigations of interface properties of Ti6Al4V/CP-Ti/Copper composite plate prepared by explosive welding

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Abstract Explosive welding technique is widely used in many industries. This technique is useful to weld different kinds of metal alloys that are not easily welded by any other welding methods. Interlayer plays an important role to improve the welding quality and control energy loss during

the collision process. In this paper, the Ti6Al4V plate was welded with a copper plate in the presence of a commercially pure titanium interlayer. Microstructure details of welded composite plate were observed through optical and scanning electron microscope. Interlayer-base plate interface morphology showed a wavy structure with solid melted regions inside the vortices. Moreover, the energy dispersive spectroscopy analysis in the interlayer-base interface reveals that there are some identified regions of different kinds of chemical equilibrium phases of CueTi, i.e. CuTi, Cu2Ti, CuTi2, Cu4Ti, etc. To study the mechanical properties of composite plates, mechanical tests were conducted, including the tensile test, bending test, shear test and Vickers hardness test. Numerical simulation of explosive welding process was performed with coupled Smooth Particle Hydrodynamic method, Euler and Arbitrary Lagrangian-Eulerian method. The multi-physics process of explosive welding, including detonation, jetting and interface morphology, was observed with simulation. Moreover, simulated plastic strain, temperature and pressure profiles were analysed to understand the welding conditions. Simulated results show that the interlayer base plate interface was created due to the high plastic deformation and localized melting of the parent plates. At the collision point, both alloys behave like fluids, resulting in the formation of a wavy morphology with vortices, which is in good agreement with the experimental results.

Mahmood Y, Dai K, Chen P, Zhou Q, Bhatti AA, Arab A. Experimental and numerical study on microstructure and mechanical properties of Ti-6Al-4V/ Al-1060 explosive welding. Metals (Basel) Nov. 2019;9(11):1189.

Mahmood Y, Chen PW. Numerical study of explosive welding with an interlayer by using SPH and ALE method. In 14th international Conference of Multiphysics. 2019.

Mahmood Y, Guo B, Chen P, Zhou Q, Bhatti AA. Numerical study of an interlayer effect on explosively welded joints. Int J Multiphys 2020;14(1):69e80.

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Processing, microstructure and mechanical properties of TiC–465 stainless steel/465 stainless steel layer composites

Journal of Alloys and Compounds 439 (2007) 287–293

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Abstract Layered composites of carbide reinforcements and stainless steel have been prepared successfully by powder technology. The layer material consisted of two layers. Top layer consisted of reinforcements (TiC and NbC) and 465 stainless steel as binder material for

carbides. The substrate material was of binder material (465 stainless steel). The microstructure of the composite was characterized by scanning electron microscopy. The microstructural study revealed that top layer (TiC–NbC/465 stainless steel) showed the typical core–rim microstructure of conventional steel bonded cermets and the substrate material showed the structure of sintered steel. An intermediate layer was formed due to diffusion reaction of top layer and substrate material. This intermediate layer showed a gradient microstructure. The bending strength of layered material measured in the direction perpendicular to the layer alignment was remarkably higher. Nineteen percent increase in bending strength in case of 53 wt% reinforcement in top layer and 35% increase in case of 73 wt% reinforcement in top layer was found. The variation of strength as a function of thickness of substrate material revealed that the character of material changed from cermet to a layer composite and then towards metallic materials. The fracture morphologies of top layer, substrate material and intermediate layer are also reported.

Microstructure characteristic of spray formed 7055 Al alloy subjected to ballistic impact by two different steel core projectiles impact

Journal of Material Research and Technology, 2019, Vol. 8(6), pp6177-6190

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Abstract: 7055 aluminium (Al) alloy was synthesized by spray forming followed by hot extrusion, later subjected to (T6 & T74) aging treatments and its mechanical properties were examined. To investigate the ballistic behavior of the semi-infinite aluminum alloy target material, ballistic test with two different types of projectiles 7.62mm soft steel core and 7.62mm armor-piercing hard steel core projectiles were carried out. Excellent mechanical properties such as; higher strength UTS 708 MPa,fracture to elongation 12.8% and hardness 240 HV were achieved in the T6 condition owing to the $MgZn_2$ phase and Al_3Zr strengthening particles. Ballistic performance of the 7055-T6 target was superior to the T74 heat treated condition in terms of depth of penetration, crater diameter, strength, ductility and hardness. The target materials were deformed seriously against armor-piercing hard steel projectile impact as compared to soft steel core projectile. The microstructure was modified within the 1–1.5mm area from the crater wall. The spray formed Al alloy have a good combination of strength and ballistic performance under the T6heat treatment condition in comparison of T74 and other alloys produced by conventional forming methods.

Corrosion Inhibition of SiC_p/5A06 Aluminum Metal Matrix Composite by Cerium Conversion Treatment

Chinese Journal of Aeronautics, Volume 22, Issue 6, December 2009, Pages 670-676

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Abstract

This article studies the effects of the $CeCl_3$ concentrations in conversion solutions with and without addition of NaCl, pH-values of conversion solution, drying temperature, time and temperature of immersion on the Ce-conversion coatings for corrosion protection of the SiC_p/5A06 Al-MMC and 5A06 Al-alloy in the 3.5% NaCl aqueous solution at room temperature. Potentiodynamic polarization tests reveal that the Ce-conversion treatment could markedly improve the pitting corrosion resistance of the composite and the matrix alloy in chloride containing environment. The best corrosion resistance effects are obtained for the samples treatment in 1‰ $CeCl_3 \cdot 7H_2O$/ 3.5% NaCl solution at 45 °C for 60 min, followed by drying at 100 °C for 30 min. Examinations by means of scanning electron microscopy (SEM), energy dispersion spectroscopy (EDS) and X-ray photoelectron spectroscopy (XPS) indicate that this behavior is due to the precipitation of Ce-oxides/hydroxides on the cathodic intermetallics and the Al-oxide film on the rest of the metal matrix.

Foundation item: Higher Education Commission (HEC) of Pakistan

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Vitae

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A Two-Dimensional Infiltration Dynamics Model of C-SiC Composites

Proceedings of the 2013 International Symposium on Liquid Metal Processing & Casting pp 333-334

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Abstract: This article presents the mathematical modeling of Si infiltration material in a porous carbon fiber preforms. Capillary infiltration kinetics in the limit of both interface and diffusion control for situations where the capillary radius decreases with time, and the contact angle was assumed constant during infiltration were studied. One major manufacturing process of the carbon fiber reinforced SiC composite materials is the liquid silicon infiltration (LSI) of a porous carbon fiber preforms to form C-SiC composites. The results show that the large-radius

(r_0 = 5 μm) capillary yields faster infiltration kinetics and longer penetration lengths than the small-diameter (r_0 = 1 μm).

Machining Research:

Systematic Geometric Error Modeling for Workspace Volumetric Calibration of a 5-axis Turbine Blade Grinding Machine

Chinese Journal of Aeronautics
Volume 23, Issue 5, October 2010, Pages 604-615

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Abstract

A systematic geometric model has been presented for calibration of a newly designed 5-axis turbine blade grinding machine. This machine is designed to serve a specific purpose to attain high accuracy and high efficiency grinding of turbine blades by eliminating the hand grinding process. Although its topology is RPPPR (P: prismatic; R: rotary), its design is quite distinct from the competitive machine tools. As error quantification is the only way to investigate, maintain and improve its accuracy, calibration is recommended for are identified while considering the machine as five rigid bodies by eliminating the set-up errors of workpiece and cutting tool. 39 of them are found to have influential errors and are accommodated for finding the resultant effect between the cutting tool and the workpiece in workspace volume. Rigid body kinematics techniques and homogenous transformation matrices are used for error synthesis.

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Vitae

Biographies:

Abdul Wahid Khan Born in 1969, he received B.S. degree from University of Engineering and Technology (UET) Lahore and M.S. degree from UET Taxila, Pakistan in 1995 and 2003 respectively. From 1996 onward he worked as metrologist in an industrial manufacturing R&D based organization. He is an expert of calibration, verification of instrument, equipment and test devices. At present he is a Ph.D. candidate at Beijing University of Aeronautics and Astronautics (BUAA), China. His research interest includes calibration of high precision multi-axis machine tools.

Chen Wuyi A professor in School of Mechanical Engineering and Automation at BUAA, China and Deputy Head of the Beijing Key Laboratory of CAD/CAM, he received his Ph.D. degree from UK and is engaged in the leading research work in the field of machining and equipment manufacturing in BUAA, China.

Radar Absorbing Materials:

Enhanced microwave absorption by arrayed carbon fibers and gradient dispersion of Fe nanoparticles in epoxy resin composites

Carbon, 2016, Vol. 96, pp987-997
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Abstract: Influences of the arrayed carbon fibers (CFs) and gradiently dispersed Fe nanoparticles (NPs) inside epoxy resin (ER) matrix on the microwave absorption and mechanical properties were investigated. As a microwave absorbent, the Fe NPs were synthesized by an arc discharge plasma method and subsequently surface-modified by using of silane coupling agent (KH-550) to improve their dispersion in organic ER matrix. To measure the naturalistic electromagnetic and mechanical properties of such nanocomposite plates, a series of square plates (20 20 cm2) were fabricated by filling the modified Fe NPs (30 wt.%) with/without orientated CFs at different mass percentages (0, 1.38 wt.%, 2.76 wt.% and 5.52 wt.%) into the ER matrix. The excellent microwave absorption of nanocomposite plate occurred as the direction of CFs was vertical to that of incident microwave, in such case the multi-reflections of microwave were caused by CFs and favors to create a great absorption probability to Fe NPs. A well matched input impedance of the plate to air is necessary for the effective entrance of incident microwave and to be attenuated by the structural resonance and electromagnetic losses. The input impedance of nanocomposite plate is mainly determined by the content of absorbent (Fe NPs with a gradient dispersion), CFs (with orientations to incident microwave, i.e. vertical, parallel or perpendicularly cross-linked to each other) and the geometric configuration (sizes of the plate, distribution of each components, etc.). It was figured out that the nanocomposite plate (30 wt.% of Fe NPs, 5.52 wt.% of CFs vertical to incident microwave) exhibits a higher reflection loss (RL) of 26.8 dB at 4.9 GHz, in which the structural resonances, appropriate conductivity, dielectric polarization and impedance matching were involved. The effects of gradiently dispersed Fe NPs and the arrayed CFs with orientations on the electromagnetic and mechanical properties were emphasized and investigated.

Design of Low RCS Circularly Polarized Patch Antenna Array Using Metasurface for CNSS Adaptive Antenna Applications

Materials, 2019, Vol. 12, 1898

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Abstract: A low radar cross section (RCS) circularly polarized patch antenna array operating at the downlink S-band (2492 ± 5 MHz) of the Chinese Compass Navigation Satellite System (CNSS) is proposed. The low RCS is achieved by replacing the conventional metallic ground with an artificial magnetic conductor (AMC)-based metasurface. Two different AMC unit cells are designed having a phase difference within 180 ± 37◦ and combined in a chessboard-like configuration to realize the AMC-based metasurface. Furthermore, the AMC-based metasurface is utilized as the ground of the CNSS array for wideband RCS reduction. A wideband RCS reduction from 6 GHz to 17 GHz is achieved due to the wideband diffusion property of the AMC unit cells. The maximum RCS reduction is more than 14 dB at 13.3 GHz irrespective of the polarization direction of the incident waves. Moreover, the circular polarization (CP) performance is realized by embedding a circular slot on the patch radiator of the antenna element. The radiation characteristics of the CNSS array are hardly impacted by the inclusion of the metasurface-based ground. The proposed CNSS array has been fabricated and measured. The measurement results are in reasonable agreement with the simulations. The proposed CNSS array can be a good candidate for CNSS adaptive antenna applications where low RCS is simultaneously demanded.

Design of a Low Scattering Metasurface for Stealth Applications

Materials, 2019, Vol. 12, 3031

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Abstract: The design of a metasurface with low radar cross section (RCS) property is presented in this paper. The low scattering of the metasurface is achieved by applying the artificial magnetic conductor (AMC) unit cells in three different configurations. Two different AMC unit cells with an effective phase difference of 180 ± 37◦ are first designed to analyze the out of phase reflection in a wideband frequency range from 5.9 to 12.2 GHz. Then, the unit cells are placed in a chessboard-like configuration, newly constructed rotated rectangular-shaped configuration, and optimized configuration to study and compare the RCS reduction performance. All designs of the metasurface with different configurations show obvious RCS reduction as compared with the metallic plate of the same size. However, the relative bandwidth of the optimized metasurface is larger than the chessboard-like configuration and rotated rectangular-shaped configuration. To certify the results of the simulations, the metasurface with the optimized configuration is fabricated further to measure the RCS reduction bandwidth. The measured results are in good

accordance with the simulated results. Therefore, the proposed metasurface can be a good option for applications where low RCS is desirable.

Stealth Considerations for Aerodynamic Configuration Design of Missiles

CADDM June 2009, Vol. 19(1)

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Abstract: The aerodynamic design of a strategic weapon is of interest, especially when the radar signatures are included in the conceptual design phase. The basics of stealth configurations and stealth mechanisms for missiles are reviewed. The Radar Cross Sections (RCS) of some generic missiles are predicted and compared to analyze the trade-offs involved between low RCS and aerodynamic performance. The consideration of RCS prediction in the conceptual design phase gives a quick insight into the stealth performance prior to detailed design.

Enhanced microwave absorption by arrayed carbon fibers and gradient dispersion of Fe nanoparticles in epoxy resin composites

Carbon, 2016, Vol. 96, pp987-997

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Abstract: Influences of the arrayed carbon fibers (CFs) and gradiently dispersed Fe nanoparticles (NPs) inside epoxy resin (ER) matrix on the microwave absorption and mechanical properties were investigated. As a microwave absorbent, the Fe NPs were synthesized by an arc discharge plasma method and subsequently surface-modified by using of silane coupling agent (KH-550) to improve their dispersion in organic ER matrix. To measure the naturalistic electromagnetic and mechanical properties of such nanocomposite plates, a series of square plates (20 20 cm2) were fabricated by filling the modified Fe NPs (30 wt.%) with/without orientated CFs at different mass percentages (0, 1.38 wt.%, 2.76 wt.% and 5.52 wt.%) into the ER matrix. The excellent microwave absorption of nanocomposite plate occurred as the direction of CFs was vertical to that of incident microwave, in such case the multi-reflections of microwave were caused by CFs and favors to create a great absorption probability to Fe NPs. A well matched input impedance of the plate to air is necessary for the effective entrance of incident microwave and to be attenuated by the structural resonance and electromagnetic losses. The input impedance of nanocomposite plate is mainly determined by the content of absorbent (Fe NPs with a gradient dispersion), CFs (with orientations to incident microwave, i.e. vertical, parallel or perpendicularly cross-linked to each other) and the geometric configuration (sizes of the plate,

distribution of each components, etc.). It was figured out that the nanocomposite plate (30 wt.% of Fe NPs, 5.52 wt.% of CFs vertical to incident microwave) exhibits a higher reflection loss (RL) of 26.8 dB at 4.9 GHz, in which the structural resonances, appropriate conductivity, dielectric polarization and impedance matching were involved. The effects of gradiently dispersed Fe NPs and the arrayed CFs with orientations on the electromagnetic and mechanical properties were emphasized and investigated.

Energetic Materials:

Ignition and Growth Modeling of Shock Initiation of Different Particle Size Formulations of PBXC03 Explosive

Journal of Energetic Materials, 34: 38–48, 2016

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The change in shock sensitivity of explosives having various explosive grain sizes is discussed. Along with other parameters, explosive grain size is one of the key parameters controlling the macroscopic behavior of shocked pressed explosives. Ignition and growth reactive flow modeling is performed for the shock initiation experiments carried out by using the in situ manganin piezoresistive pressure gauge technique to investigate the influences of the octahydro-1,3,5,7–tetranitro1,3,5,7-tetrazocine (HMX) particle size on the shock initiation and the subsequent detonation growth process for the three explosive formulations of pressed PBXC03 (87% HMX, 7% 1,3,5-trichloro2,4,6-trinitrobenzene (TATB), 6% Viton by weight). All of the formulation studied had the same density but different explosive grain sizes. A set of ignition and growth parameters was obtained for all three formulations. Only the coefficient G1 of the first growth term in the reaction rate equation was varied with the grain size; all other parameters were kept the same for all formulations. It was found that G1 decreases almost linearly with HMX particle size for PBXC03. However, the equation of state (EOS) for solid explosive had to be adjusted to fit the experimental data. Both experimental and numerical simulation results show that the shock sensitivity of PBXC03 decreases with increasing HMX particle size for the sustained pressure pulses (around 4 GPa) as obtained in the experiment. This result is in accordance with the results reported elsewhere in literature. For future work, a better approach may be to find standard solid Grüneisen EOS and product Jones-WilkinsLee (JWL) EOS for each formulation for the best fit to the experimental data.

Influence of Small Change of Porosity on Shock Initiation of an HMX/TATB/Viton Explosive and Ignition and Growth Modeling

Journal of Energetic Materials, 34: 246–259, 2016

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All solid explosives in practical use are more or less porous. Although it is known that the change in porosity affects the shock sensitivity of solid explosives, the effect of small changes in porosity on the sensitivity needs to be determined for safe and efficient use of explosive materials. In this study, the influence of a small change in porosity on shock initiation and the

subsequent detonation growth process of a plastic-bonded explosive PBXC03, composed of 87% cyclotetramethylene-tetranitramine (HMX), 7% triaminotrinitrobenzene (TATB), and 6% Viton by weight, are investigated by shock to detonation transition experiments. Two explosive formulations of PBXC03 having the same initial grain sizes pressed to 98 and 99% of theoretical mass density (1.873 g/cm3) respectively are tested using the in situ manganin piezoresistive pressure gauge technique. Numerical modeling of the experiments is performed using an ignition and growth reactive flow model. Reasonable agreement with the experimental results is obtained by increasing the growth term coefficient in the Lee-Tarver ignition and growth model with porosity. Combining the experimental and simulation results shows that the shock sensitivity increases with porosity for PBXC03 having the same initial grain sizes pressed to 98 and 99% of theoretical mass density (1.873 g/cm3) respectively are tested using the in situ manganin piezoresistive pressure gauge technique. Numerical modeling of the experiments is performed using an ignition and growth reactive flow model. Reasonable agreement with the experimental results is obtained by increasing the growth term coefficient in the Lee-Tarver ignition and growth model with porosity. Combining the experimental and simulation results shows that the shock sensitivity increases with porosity for PBXC03 having the same explosive initial grain sizes for the pressures (about 3.1 GPa) applied in the experiments.

Shockwave Research:

Comparative Study of Modern Shock Capturing Schemes

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Abstract The construction of efficient high order low dissipation numerical methods for nonlinear hyperbolic conservation laws has been the subject of much research recently. The objective of the present work is to discuss the applicability and limitation of the Low Dissipative High Order ACM and TVD finite-difference methods for various flow problems. Three different limiters are used for TVD scheme to compare results with ACM method. Hypersonic flows over a flat plate, compression corner, and rearward facing step are solved for comparative study， and comparison is made between numerical and available experimental results.

Reactor Research:

Thesis:

Conceptual Design and Efficiency Optimization of Power Generation System for Lead-based Nuclear Energy System

Muhammad Salman Khan

【摘要】： Due to the good neutronics,thermal hydraulics and safety characteristics of lead-based coolants,Lead-based Nuclear Energy Systems(LNESs)have generated great interest in the research field of international advanced nuclear energy systems,including the lead and lead-bismuth cooled fission reactors and the Lithium Lead(LiPb)cooled fusion reactors.Based on the high boiling point characteristics of the lead-based coolant,the core outlet temperature of the LNESs can reach above 500℃.Therefore,the LNESs have the potential to achieve high power

generation efficiency.Recently,the power generation system based on lead and lead-bismuth cooled fission reactors and LiPb cooled fusion reactors have performance in the range of～40%and～46%,respectively.Under the same core outlet temperature condition,improving the power generation efficiency by optimizing the scheme and parameters of the power generation system is of excessive significance for improving the economics of LNESs.The conceptual design and optimization of the steam Rankine power generation system of Lead-cooled Fast Reactor(LFR)and the Helium-gas(He-gas)cooled Brayton power generation system of the LiPb cooled fusion reactor have been carried out in this workA conceptual design of power generation system with two reheaters has been proposed for a 400 MWth LFR with lead inlet and outlet temperature from the core about 400℃ and 500℃,respectively.Three different schemes of power generation system have been design and named as Schematics Ⅰ,Ⅱ and Ⅲ.The thermal efficiency of Schematic-Ⅲ with two reheaters was 44.3%and higher than Schematic-Ⅰ and Ⅱ;one reheater with bleed-off steam from the supply line of the first regenerator and main supply line,respectively.The thermal efficiency was influenced by the number of reheaters(with bleed-off steam at different positions).The optimized temperature of feed water at the inlet of the reactor was 360℃ with a flow rate of 237 kg/s,the outlet temperature of the reactor was 558℃,optimized turbine pressure was 22 MPa and the condenser back pressure was 0.004 MPa,respectively.The efficiency and net power of the plant were increased with the part load.The results showed that efficiency of the plant was increased by as much as ranges from 49.5%to 52.3%at the optimized parameters of the power generation system of LFRThe design of the Steam Generator(SG)utilizes the Bayonet-tube based technology with steel T91 as a structural material for the LFR.The heat extraction capacity of single SG is 50 MW and the total number of tubes is 510.The temperature of steam at the outlet is increased by 16℃,the efficiency of the plant is increased by 1%and the power generated by the plant is increased by～6-7 MW for the increase of feed water temperature 5℃ each time,ranges between 335℃ and 356℃.The heat transfer is increased about 8 MWth for the every increase in mass flow rate 5 kg/s of feed water.A modified design of the power generation system with concept of two-stage expansions named Schematic-Ⅳ,which work on the bases of He-gas cooled Brayton cycle has been proposed for the Dual-coolant LiPb(DLL)blanket of FDS-II to increase the power generation efficiency of the system than the previous design.Total extraction of the blanket was 21 MW,He-gas temperature and pressure at the exit of intermediate heat exchanger was 680℃ and 8 MPa.The engineering equation solver tool was used to calculate the performance of the system.More than one expansion stage is very effective as compared with either splitting the flow equally for the expansion in two turbines or a single-stage expansion.The thermal efficiency of the Schematic-Ⅳ was 51%,which was 4%higher than the previous designs.The optimum pressure ratio was 3.41 to obtain the maximum thermal efficiency of 65.3%.An intermediate heat exchanger with a corrugation structure has been proposed to increase the power generation efficiency and the safety of fusion reactor system.The corrugated structure of Compact Heat Exchanger(CHE)with SiCf/SiC composite has higher 11.4%heat transfer rate as compared to that with ODS steel.According to the design parameters of the DLL,corrugated structure of the CHE increased the effectiveness and overall heat transfer coefficient up to 19.8%and 25.1%at the LiPb velocity of 0.099 m/s and increased up to 26.2%and 33.0%,when the velocity of LiPb was decreased to 0.012 m/s as compared to that of flat structure of compact heat exchanger.An efficient and reliable experimental setup of the power generation system for LNES can be developed based on this study.The optimum number of reheaters for Rankine cycle and number

of expansion stages for the Brayton cycle should be considered properly to increase the performance of the system.The parameters of the power generation system can be optimized by using this study as a reference.

Conceptual design and numerical assessment of compact heat exchanger for lead-based reactor

Progress in Nuclear Energy, 2020, Vol. 124, 103348

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ABSTRACT A conceptual design of compact and highly efficient heat exchanger has been developed and proposed for the 10 MWth lead-based reactor using mathematical and numerical methods. Lead Bismuth Eutectic (LBE) and Pressurized Liquid Water (PLW) are selected as working fluid across the hot and cold sides of the Compact Heat Exchanger (CHE). The mathematical method based on energy balance equations has been used to develop the design of CHE with complete specifications of structural parameters. While, in the numerical method, FLUENT has been used to analyze and evaluate the detailed observation of thermal performance, Stanton number, and development of the irreversible heat transfer by the Bejan number. The thermal performance of CHE can be controlled with the flow rate of the PLW. The maximum overall heat transfer coefficient and effectiveness were 7528 W·m 2 K 1 and 0.79, respectively. The thermal-hydraulic analysis involves the assessment of Nusselt number (Nu), temperature contour, and velocity vector and stream line. The numerical simulation results are agreed well with the correlation and the error is within ranges of ~ 2- 8%. This study can be used as a reference for the development and design of a compact and efficient heat exchanger for lead-based reactors.

Conceptual design and optimization of power generation system for lead-based reactor

Applied Thermal Engineering, 2020, Vol. 168, 114714

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ABSTRACT: The lead-based reactor is one of the key nuclear energy systems for Generation-IV (Gen-IV) and Accelerator Driven Subcritical Systems (ADS). The Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences (INEST, CAS) has taken significant initiative for the design and development of the China Lead-based Reactor (CLEAR) series since 2011. The conventional power generation system has low performance and optimization of main parameter is a challenge when power generation system is connected with lead-based reactor. A new/modified conceptual design of an efficient power generation system with two reheaters has been proposed on the basis of a 400 MWth (thermal power) lead-based reactor with high performance. The analysis results show that the thermal efficiency was influenced by number of

reheaters (with bleed-off steam at different positions). The thermal efficiency of Schematic-III (with two reheaters) was 44.3% and higher than Schematic-I and II (one reheater with bleed-off steam from the supply line of the first regenerator and main supply line, respectively). However, key parameters of the power generation system have been optimized to increase the overall performance of Schematic-III. The optimized temperature of feed water at the inlet of the reactor was 360 °C with a flow rate of 237 kg·s−1 and the outlet temperature of the reactor was 558 °C. The efficiency and net power of the plant increased with the part load.

Detailed neutronic analysis of a MOX-fueled metal-cooled reactor

Annals of Nuclear Energy, 2018, Vol. 114, pp427-436

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SuperMC BFS-62-3A Stainless steel reflector Code-to-code verification Sodium void reactivity effect abstract With the prominent features of different U-Pu fuel compositions, the MOX-fueled fast spectrum metal cooled reactors have been of increasing interest for recent years worldwide. Present study invokes a detailed investigation on the calculations for neutronic analysis and it conducts a comparative study for neutron physics parameters of a metal-cooled fast spectrum reactor – the BFS-62-3A. This work is an amalgamation of four tasks. In the first part, a detailed comparative analysis was performed to perform a code-to-code verification using the available results of three Monte Carlo codes including SuperMC, MCNP, and Serpent, and a deterministic one, the DYN3D-MG with the employment of continuous neutron energy cross-sections. The experimental results of BFS-62-3A benchmark were used to assess the potentiality of the aforementioned reactor physics codes. For most of the integral parameters, the SuperMC was found to be on the leading edge. In the second part, the effects of data libraries including ENDF/B-7.1, ENDF/B-7.0, ENDF/B-6.6, JEFF3.2, and HENDL3.0 on the simulations performed using SuperMC code for evaluating k-eff and radial fission rates were all assessed. The third part incorporates the investigation of the fission rates' deviations in stainless steel radial reflector by changing the density of the reflector. The decrease of density by 5% was found to be in good agreement with the benchmark. In the last part, that has a special importance to the concept pertaining to safety-enhanced Sodium-cooled Fast Reactor (SFR) core, the reactivity of the critical assembly was studied by calculating the sodium void reactivity effect. The simulation results of SuperMC code agreed well with the available experimental and simulation results. The present study has enabled SuperMC code to pass another big milestone on dealing with complex and advanced nuclear systems.

Design and analysis of thermal hydraulic performance of compact heat exchanger for FDS-II auxiliary system

Fusion Engineering and Design, 2019, Vol. 147, 222251

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ABSTRACT One key issue of a fusion power plant is the requirement of highly efficient heat extraction from the primary loop to ensure the safety and reliability. The Dual-coolant Lithium Lead (DLL) breeder blanket of the FDS-II with a compact heat exchanger (CHE) is one design option for the power extraction system, and the Lithium Lead eutectic (LiPb) and helium gas are used as the thermal fluids. In this work, the flat and corrugated plate structures with SiCf/SiC composites and ODS steel were designed for the comparison of thermal performance. The heat transfer rate of the SiCf/SiC was 11.4% higher as compared to the ODS steel and was chosen as a candidate structural material. According to the design parameters of the DLL, effectiveness and the overall heat transfer coefficient for the corrugated structure increased up to 19.8% and 25.06% at the LiPb velocity of 0.099 m/s and increased up to 26.2% and 33.03%, when the velocity of the LiPb decreased to 0.012 m/s. The Nusselt number for the LiPb and helium gas was calculated for the convective heat transfer. The numerical results agreed well with the correlations within a deviation of~2%. In addition, pressure drop of the corrugation structure increased but it can be neglected as compared to the increase in the thermal performance. The concept of CHE with the SiCf/SiC structure could be applied to the design of intermediate heat exchanger working in a fusion power plant.

Thermodynamic Analysis of Combined Cooling Heating and Power System with Absorption Heat Pump Based on Small Modular Lead-based Reactor

E3S Web of Conferences, 2021, Vol. 245, 01025

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Abstract. Small Modular Lead-based Reactor (SMLR) has generated great interest in academic research all around the world due to its good safety characteristics and relatively high core outlet temperature. In this paper, a Combined Cooling Heating and Power (CCHP) system with usage of absorption heat pump, which couples with a SMLR, was proposed to fulfill the energy demands in remote areas. Thermodynamic analysis was implemented to improve the performance of the CCHP system based on SMLR. To meet the remote areas' energy needs, the main parameters and mass flow rate of a 35 MWth SMLR design were analyzed. The SMLRCCHP with absorption heat pump system can provide electric power 12.5MWe, heating 9.5MWh, and cooling 2.54MWc. The total energy utilization efficiency of the system can be 69.12 %. This work can provide a reference in the design and optimization of the CCHP system to meet the energy demands in the remote areas.

Thermal hydraulic analysis of concentric recuperator of DRAGON-V loop

Fusion Engineering and Design, 2019, Vol. 14, pp13-19

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ABSTRACT An experimental Lead Lithium (PbLi) loop named DRAGON-V has been built at the Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences (INEST, CAS). The purpose of this loop is to test the technical issues of PbLi blankets for fusion reactors, such as thermal hydraulics, material corrosion, magnetohydrodynamics (MHD) effect and safety issues, etc. The main heat recovery system of the DRAGON-V loop is the Concentric Recuperator Heat Exchanger (CRHE) which was made of T91 steel. It has counter flow arrangements with PbLi as the working fluid across the tube and shell sides. In this paper, the system was analyzed in detail for thermal performance, pressure drop, pumping power, entropy generation, the effect of inlet temperature of shell side fluid on overall performance, and the temperature distribution and flow characteristics. It was found that the effectiveness and heat transfer rate of the CRHE was decreased with the inlet temperature of the PbLi across the shell side. The difference of effectiveness calculated by correlation and simulation was about 4.5%. The high pumping power of PbLi fluid circulation was required on the shell side due to its thermo-physical properties variation, which resulted in the high pressure drop across the shell side as compared to the tube side. The temperature variation across the tube and shell sides indicated that the simulation results agreed well with the design parameters within a deviation of less than ˜5%.

Conceptual design and optimization of cogeneration system based on small modular lead-cooled fast reactor

Energy Science and Engineering, 2019, Vol. 9, pp1688-1702

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Abstract: Cogeneration system based on Small Modular Lead-cooled Fast Reactor (SMLFR) becomes attractive due to its good characteristics of flexible location, safety, thermal efficiency, and economy. The conventional cogeneration systems using coal, gas, or renewable energy as the thermal resource have lower thermal performance as compared to LFR based cogeneration systems due to lack of sustainable energy resources. A modified concept design of cogeneration system based on a 35-MWth SMLFR has been proposed to improve the thermal performance. A new concept of District Heating (DH) structure layout along with optimization based on the exhaust steam/water drainage position. The thermodynamic model based on energy and exergy methods has been used to design and calculate the energy losses of the cogeneration system components. The energy utilization rate can be increased significantly by optimizing the DH. The thermal efficiency of the proposed system reaches up to 73.64% with an increase of 3.51% and the exergy efficiency reaches up to 59.31% with an increase of 5.01%. The increase of

thermal performance under the different heating demands will lead to better energy conservation and environmental safety. This study can be further used as the reference for the design and optimization of SMLFR cogeneration system based on thermodynamic and exergy analysis.

Numerical analysis of thermal performance of heat exchanger: Different plate structures and fluids

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Abstract Due to compact size, high power density, low cost and short construction time, the Small Modular Reactors (SMRs) are considered as one of the candidate reactors, in which the power generation system is important with a compact heat exchanger for modular construction. Therefore, the effect of plate structure and nature of the working fluid on the thermal performance of Plate Heat Exchanger (PHE) are analyzed for the design of compact and efficient heat exchanger. The heat transfer rate, temperature counters, velocity vectors and pressure drop have been optimized and investigated using FLUENT. The Nusselt number has been calculated for the corrugated and flat PHE to validate the convective heat transfer. The numerical results are agreed well with correlation within deviation of ~ 5-7%. The performance of heat exchanger can be improved by controlling the mass flow rate and temperature of working fluid. The corrugation PHE increases the heat transfer rate 20 % and effectiveness 23 %, respectively, as compare to flat PHE when the working fluid is water. In the case of air, heat transfer rate and effectiveness are about 10 % and 9 %, respectively. The results show that the corrugated PHE is more effective than the flat PHE because corrugation pattern enhances the turbulence of fluids, which further increase heat transfer rate and coefficient. The selection of the working fluid and structure of the plate must be considered carefully for efficient and compact design of heat exchanger.

Performance Optimization of Power Generation System for Helium Gas/Lead Lithium Dual-coolant Blanket System

- Muhammad Salman Khan, Qunying Huang, Yunqing Bai & Zhibin Chen

Journal of Fusion Energy, volume 40, Article number: 6 (2021)

Abstract

Helium gas (He-gas) / Lithium Lead (LiPb) Dual-cooled LiPb (DLL) blanket is one of the promising candidates for the DEMO fusion reactor for power generation. Brayton cycle based on He-gas has been used as the power generation system for the fusion and fission power reactors. In this work, a modified and efficient design of the power generation system with concept of two stage expansions and one intercooler named as Schematic-I has been proposed for the DLL blanket of Fusion Power Reactor (FDS-II) to increase the thermal performance (e.g. power density and efficiency) of the system and optimized the parameters of the system. The engineering equation solver tool was used to calculate the performance of the system. It is found that the use of more than one expansion stage with proper selection of intercooler is very

effective as compared with either splitting the flow equally for the expansion in two turbines or a single stage expansion. The concept of two-stage expansions in the Schematic-I increased the thermal efficiency of the system up to 51%, which was 4% higher than previous design of DLL blanket power generation system. The main parameters of the system such as isentropic efficiency of turbine and compressor, pressure ratio, recuperator performance, the terminal temperature difference of the recuperator, the inlet temperature of DLL blanket and effect of different pressures on the system have all been analyzed and optimized to achieve high performance.

Spacecraft Related Research:

Pakistan Space Programme and International Cooperation: History and Prospects

Space policy, 2019, Vol. 147, pp175-180

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Abstract: Pakistan was among the first 10 countries to start a space programme. Its space programme started upon the appointment of Dr. Abdus Salam (Noble Prize Winner) as the Chairman of the Space Upper Atmosphere Research Commission (SUPARCO) in 1961. Owing to the prevailing unfavourable economic and political environment, coupled with regional instability and other factors, this programme could not persist for long. Recent efforts to overcome these mistakes and hurdles through an improved domestic strategy and smarter international relations are promising. Notably, success in this area can be ensured only with sustained political commitment to space development. To promote its space activities, Pakistan successfully conducted international cooperation with different countries and organisations. This article examines the Pakistan space programme and its cooperation with other countries, in particular, the shift in partnership from the United States to China.

Motion stability dynamics for spacecraft coupled with partially filled liquid container

THEORETICAL & APPLIED MECHANICS LETTERS 2, 013002 (2012)

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Abstract This paper presents a canonical Hamiltonian model of liquid sloshing for the container coupled with spacecraft. Elliptical shape of rigid body is considered as spacecraft structure. Hamiltonian system is an important form of mechanical system. It mostly used to stabilize the potential shaping of dynamical system. Free surface movement of liquid inside the container is called sloshing. If there is uncontrolled resonance between the motion of tank and liquid-frequency inside the tank then such sloshing can be a reason of attitude disturbance or structural damage of spacecraft. Equivalent mechanical model of simple pendulum or mass attached with spring for sloshing is used by many researchers. Mass attached with spring is used as an equivalent model of sloshing to derive the mathematical equations in terms of Hamiltonian

model. Analytical method of Lyapunov function with Casimir energy function is used to find the stability for spacecraft dynamics. Vertical axial rotation is taken as the major axial steady rotation for the moving rigid body.

Hamiltonian Structure and Stability Analysis for a Partially Filled Container

Journal of Mechanics, Volume 29(1), **16 October 2012**

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Abstract

Hamiltonian system is a special case of dynamical system. Mostly it is used for potential shaping of mechanical systems stabilization. In our present work, we are using Hamiltonian dynamics to study and control the fuel slosh inside spacecraft tank. Sloshing is the phenomenon which is related with the movement of fluid inside a container in micro and macro scale as well. Sloshing of fluid occurs whenever the frequency of container movement matches with the natural frequency of fluid inside the container. Such type of synchronization may cause the structural damage or could be a reason of moving object's attitude disturbance. In spacecraft technology, the equivalent mechanical model for sloshing is common to use for the representation of fuel slosh. This mechanical model may contain a model of pendulum or a mass attached with a spring. In this article, we are using mass-spring mechanical model coupled with rigid body to derive the equations for Hamiltonian system. Casimir functions are used for proposed model. Conditions for the stability and instability of moving mass are derived using Lyapunov function

along with Casimir functions. Simulation work is presented to strengthen the derived results and to distribute the stable and unstable regions graphically.

Low-Cost Dual-Band Circularly Polarized Switched-Beam Array for Global Navigation Satellite System

IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 62, NO. 4, APRIL 2014
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The prize was awarded at the International Technical Meeting of the Institute of Navigation in Newport Beach, CA, USA, in 2011 and recognizes his pioneering work in the development of low-cost GNSS receiver technology for spaceborne navigation and remote sensing.

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B.I. Underwood received the B.Sc. degree (Hons) in physics with computer science from the University of York, York, U.K., in 1982. After gaining a Post Graduate Certificate in Education from the University of York in 1983. He received the Ph.D. degree in space radiation environment and effects in 1996 from University of Surrey, Guildford, U.K. In 1983, he began a teaching career at Scarborough Sixth-Form College where he developed satellite activities. In January 1986, he joined the University of Surrey as a Research Fellow responsible for the generation and maintenance of software for the UoSAT Satellite Control Ground-Station. In 1988, as a Senior Engineer with Surrey Satellite Technology Ltd. (SSTL), Guildford, he became responsible for mission analysis and the thermal design of the UoSAT spacecraft, including: UoSAT-3, -4, and -5, KITSAT-1, S80/T, HealthSat-II, PoSAT-1 and FASat-Alfa. Since 1990, he has been Surrey's Principal Investigator of Space Radiation Environment and Effects. In 1993, he became a Lecturer in Spacecraft Engineering advancing to Senior Lecturer in 1999, Reader in April 2003, and Professor in 2012.

Abstract—This paper presents the design and development of a dual-band switched-beam microstrip array for global navigation satellite system (GNSS) applications such as ocean reflectometry and remote sensing. In contrast to the traditional Butler matrix, a simple, low cost, broadband and low insertion loss beam switching feed network is proposed, designed and integrated with a dual band antenna array to achieve continuous beam coverage of around the boresight at the L1 (1.575 GHz) and L2 (1.227 GHz) bands. To reduce the cost, microstrip lines and PIN diode based switches are employed. The proposed switched-beam network is then integrated with dual-band step-shorted annular ring (S-SAR) antenna elements in order to produce a fully integrated compact-sized switched-beam array. Antenna simulation results show that the switched-beam array achieves a maximum gain of 12 dBic at the L1 band and 10 dBic at the L2 band. In order to validate the concept, a scaled down prototype of the simulated design is fabricated and measured. The prototype operates at twice of the original design frequency, i.e., 3.15 GHz and 2.454 GHz and the measured results confirm that the integrated array achieves beam switching and good performance at both bands.

M. Maqsood, B. Bhandari, S. Gao, R. D. Steenwijk, and M. Unwin, “Development of dual-band circularly polarized antennas for GNSS remote sensing onboard small satellites,” presented at the ESA Workshop on Antennas for Space Applications, ESTEC, The Netherlands, 2010.

Spacecraft Launch Vehicles:

Multidisciplinary Design of Air-launched Satellite Launch Vehicle Using Particle Swarm Optimization

18th World IMACS / MODSIM Congress, Cairns, Australia 13-17 July 2009

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Abstract: Launch vehicle design is a complex, multidisciplinary engineering activity that requires making difficult compromises to achieve a balance among competing objectives for the vehicle, including safety, reliability, performance, operability, and cost. Significant work has been done in recent years to advance the design, analysis and optimization of launch vehicles. In the present research effort we propose the application of Particle Swarm Optimization (PSO) in devising a Multidisciplinary Design and Optimization (MDO) strategy for designing a multistage Air-launched Satellite Launch Vehicle (ASLV) with a solid fueled propulsion system. The detailed modules for propulsion characteristics, aerodynamics, mass properties and flight dynamics have been integrated to produce a high fidelity multidisciplinary model of the entire vehicle. Design and optimization of an ASLV is a challenging undertaking and differs from conventional ground launched SLVs. A major difference is in the launch phase, that is, it has to be carried on a mother aircraft to a certain altitude and then launched in a horizontal direction (Flight Path Angle (FPA) = 0 deg). Another difference is in the aerodynamics, that is, ASLV has aerodynamic lifting surfaces in order to improve stability and to provide lift during both the launch phase and within atmospheric flight. A lack of availability of literature on MDO for an ASLV makes our problem even more complex and difficult. PSO is a relatively recent heuristic search method whose mechanics are inspired by swarming or collaborative behavior of biological populations. Simplicity of coding and relatively less computational cost makes PSO a very attractive choice for our problem. PSO has been used as a global optimizer to achieve an optimal solution for attaining a minimum Gross Launch Weight (GLW) while remaining within the set constraints and ensuring delivery of the payload to the desired orbit. The objective of this paper is to develop a design strategy based on PSO that proves to be effective (finding the true global optimal solution) with much better computational efficiency (least computational time) and facilitates system design and optimization of ASLV at the preliminary design level. Use of PSO in system design and optimization of the ASLV makes the present research innovative. The design approach is meant for initial design sizing purposes with minimum basic vehicle data but gives a quick insight on the vehicle performance prior to detailed design.

Rafique, A.F., Linshu, H., Zeeshan, Q., Kamran, A., “Multidisciplinary Design of Air Launched Satellite Launch Vehicle using Particle Swarm Optimization”, Proceedings of 18th World IMACS / MODSIM Congress, Australia, 13-17 July 2009.

Small Launch Vehicle Trajectory Profile Optimization Using Hybrid Algorithm

Proceedings of 2013 10th International Bhurban Conference on Applied Sciences & Technology (IBCAST) 163 Islamabad, Pakistan, 15th - 19th January, 2013

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Abstract- A hybrid optimization approach combining a genetic algorithm (GA) with sequential quadratic programming (SQP) has been used for optimization of the trajectory profile of a three stage solid propellant small launch vehicle configured from existing solid rocket motors. The selected launch vehicle (LV) is capable of delivering a small satellite of 80 kg to a low earth orbit (LEO) of 660 km altitude. This hybrid optimization approach combines the advantage of GA as a global optimizer and complemented with SQP to find the local optimum. The vertical flight time, launch maneuver variable, maximum angle of attack, coasting time between the first and second stage and the second coasting time between the second and third stage were optimized. It is shown that the proposed hybrid optimization approach was able to find the convergence of the optimal solution with very acceptable values.

Q. Zeeshan, Y. Dong, K. Nisar, et al. Multidisciplinary design and optimization of multistage ground-launched boost phase interceptor using hybrid search algorithm. Chinese Journal of Aeronautics 2010; 23(2): l70-l78.

M. Qazi, He Linshu, Nearly orthogonal sampling and neural network metamodel driven conceptual design of multistage space launch vehicle, Journal of Computer Aided Design 38 (2006), 2006.

M. Qazi, He Linshu, Rapid trajectory optimization using computational intelligence for guidance and conceptual design of multistage space launch vehicle, in: Proceedings of the AIAA Guidance, Navigation and Control Conference, AIAA 2005-6062, 2005

Hyper Heuristic Approach for Design and Optimization of Satellite Launch Vehicle

Chinese Journal of Aeronautics, 2011, Vol. 24, pp150-163

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Abstract Satellite launch vehicle lies at the cross-road of multiple challenging technologies and its design and optimization present a typical example of multidisciplinary design and optimization (MDO) process. The complexity of problem demands highly efficient and effective algorithm that can optimize the design. Hyper heuristic approach (HHA) based on meta-heuristics is applied to the optimization of air launched satellite launch vehicle (ASLV). A non-learning random function (NLRF) is proposed to control low-level meta-heuristics (LLMHs) that increases certainty of global solution, an essential ingredient required in product conceptual design phase of aerospace systems. Comprehensive empirical study is performed to evaluate the performance advantages of proposed approach over popular non-gradient based optimization methods. Design of ASLV encompasses aerodynamics, propulsion, structure, stages layout, mass distribution, and trajectory modules connected by multidisciplinary feasible design approach. This approach formulates explicit system-level goals and then forwards the design optimization process entirely over to optimizer. This distinctive approach for launch vehicle system design relieves engineers from tedious, iterative task and enables them to improve their component level models. Mass is an impetus on vehicle performance and cost, and so it is considered as the core of vehicle design process. Therefore, gross launch mass is to be minimized in HHA.

Multidisciplinary design of air-launched space launch vehicle using simulated annealing. In: Mertsching B, Hund M, Aziz Z. Lecture Notes in Computer Science 5803 LNAI. Berlin Heidelberg: Springer-Verlag, 2009; 719-726, Rafique A F, He L S, Zeeshan Q, et al.

Multidisciplinary Design and Optimization of Satellite Launch Vehicle Using Latin Hypercube Design of Experiments

AMER Farhan Rafique, HE Lin-shu, QASIM Zeeshan (School of Astronautics, Beijing University of Aeronautics and Astronautics, Beijing 100191, China)

Abstract: The design of new Satellite Launch Vehicle (SLV) is of interest, especially when a combination of Solid and Liquid Propulsion is included. Proposed is a conceptual design and optimization technique for multistage Low Earth Orbit (LEO) bound SLV comprising of solid and liquid stages with the use of Genetic Algorithm (GA) as global optimizer. Convergence of GA is improved by introducing initial population based on the Design of Experiments (DOE) Technique. Latin Hypercube Sampling (LHS)-DOE is used for its good space filling properties. LHS is a stratified random procedure that provides an efficient way of sampling variables from their multivariate distributions. In SLV design minimum Gross Lift off Weight (GLOW) concept is traditionally being sought. Since the development costs tend to vary as a function of GLOW, this minimum GLOW is considered as a minimum development cost concept. The design approach is meaningful to initial design sizing purpose for its computational efficiency gives a quick insight into the vehicle performance prior to detailed design.

Hyper Heuristic Approach for Design and Optimization of Satellite Launch Vehicle

Chinese Journal of Aeronautics, 2011, Vol. 24, p150-163

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Received 6 January 2010; revised 10 March 2010; accepted 25 September 2010

Abstract Satellite launch vehicle lies at the cross-road of multiple challenging technologies and its design and optimization present a typical example of multidisciplinary design and optimization (MDO) process. The complexity of problem demands highly efficient and effective algorithm that can optimize the design. Hyper heuristic approach (HHA) based on meta-heuristics is applied to the optimization of air launched satellite launch vehicle (ASLV). A non-

learning random function (NLRF) is proposed to control low-level meta-heuristics (LLMHs) that increases certainty of global solution, an essential ingredient required in product conceptual design phase of aerospace systems. Comprehensive empirical study is performed to evaluate the performance advantages of proposed approach over popular non-gradient based optimization methods. Design of ASLV encompasses aerodynamics, propulsion, structure, stages layout, mass distribution, and trajectory modules connected by multidisciplinary feasible design approach. This approach formulates explicit system-level goals and then forwards the design optimization process entirely over to optimizer. This distinctive approach for launch vehicle system design relieves engineers from tedious, iterative task and enables them to improve their component level models. Mass is an impetus on vehicle performance and cost, and so it is considered as the core of vehicle design process. Therefore, gross launch mass is to be minimized in HHA.

Nearly-orthogonal sampling and neural network metamodel driven conceptual design of multistage space launch vehicle

Computer-Aided Design, 2006, Vol. 38, pp595-607

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Abstract This paper presents a new design methodology for efficient conceptual design of complex systems involving multidisciplinary and computationally intensive analysis with large number of design variables. A nearly-orthogonal sampling of design space is proposed with good space filling properties to extract maximum useful information about system behavior using much lower number of trial designs. This sampled data is then used as training data for artificial neural network, which will act as a metamodel to represent the time consuming disciplinary analyses. A stage-wise interconnection of separate neural networks is also proposed for trajectory metamodel to offset dimensionality curse of neural networks. Genetic Algorithm performs global optimization by utilizing this metamodel and subsequently sequential quadratic programming performs the local optimization utilizing exact analyses. The performance of proposed methodology is investigated in this paper for the conceptual design optimization of multistage solid fueled space launch vehicle. The results show excellent approximation of highly non-linear functions using proposed sampling and drastic reduction in overall design optimization time, due to greatly reduced number of exact disciplinary analyses.

Multidisciplinary design of air launched satellite launch vehicle: Performance comparison of heuristic optimization methods

Acta Astronautica, 2010, Vol. 67, pp826-844

Amer Farhan Rafique , He LinShu, Ali Kamran, Qasim Zeeshan School of Astronautics, Beijing University of Aeronautics and Astronautics (BUAA), 37 XueYuan Road, HaiDian District, Beijing 100191, PR China

Abstract: Satellite launch vehicle design lies at the cross-road of multiple challenging technologies and its design and optimization presents a typical example of multidisciplinary design and optimization process. The complexity of problem demands for highly efficient and effective algorithm that can optimize the design. This research effort aims to evaluate and

compare three modern heuristic optimization methods for multidisciplinary design and optimization of air launched satellite launch vehicle. Furthermore, sensitivity analysis of solutions presented the robustness of solution of these methods under parametric uncertainty. The Monte Carlo simulation method conducted the sensitivity analysis of the solutions. Heuristic optimization methods evaluated for current research include genetic algorithm, particle swarm optimization and simulated annealing. Genetic algorithm has been the most popular choice of designers for satellite launch vehicles. Application of other two methods in design and optimization of satellite launch vehicles is rare and thus become the motivational ingredient for the present research.

Integrated System Design of Air Launched Small Space Launch Vehicle using Genetic Algorithm

45th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit 2 - 5 August 2009, Denver, Colorado

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Design of launch vehicles is highly complex undertaking and it involves a number of integrated disciplines and relatively a large number of design variables, so there is need of specialized state-of-the-art design tools to control overall design process and optimize the performance of vehicle itself. In this paper we propose an integrated system design approach for multidisciplinary conceptual design and optimization of multistage Air Launched Space Launch Vehicle comprising of three-stage solid propulsion system. The vehicle performance modeling requires that analysis from four separate disciplines be integrated into the design optimization process. The disciplines of propulsion characteristics, aerodynamics, mass properties, and flight dynamics have been integrated to produce a high-fidelity system model of the entire vehicle. Genetic algorithms have been chosen as optimizer because of their robustness and their efficient capacity to explore the design space. The objective is to develop an integrated system design approach that can more efficiently (less computational time) and effectively (solution quality) facilitate integrated design analysis and optimization for Air Launched Space Launch Vehicle at conceptual design level under certain mission and flight constraints. The mission of the ASLV is to deliver a small satellite of 200kg to Low Earth Orbit with minimum possible Gross Launch Mass. The proposed design approach is meant for initial design sizing purposes but gives a quick insight on the vehicle performance prior to detailed design with minimum basic vehicle data.

Nearly-orthogonal sampling and neural network metamodel driven conceptual design of multistage space launch vehicle

Computer-Aided Design
Volume 38, Issue 6, June 2006, Pages 595-607

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Vitae

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HE Linshu Born in 1938 in ChangSha, Hunan, China. In 1960, he graduated from Beijing University of Aeronautics and Astronautics (BUAA) in flight vehicle design. Since then he is faculty member of BUAA. From 1982 to 1984, he was visiting scholar in Department of Mechanical Engineering of New Jersey Institute of Technology, NJ, USA. There, he worked on structural optimization and computer aided design. Presently he is professor in the School of Astronautics, BUAA. His teaching and research fields are flight vehicle design and Multidisciplinary Design Optimization (MDO). He is author of 3 text books and more than 30 research papers in Chinese and English. He has supervised more than 30 Chinese and foreign doctoral and masters students. Tel: +86 10 82316719, E-mail: helinshu@sina.com

Abstract

This paper presents a new design methodology for efficient conceptual design of complex systems involving multidisciplinary and computationally intensive analysis with large number of design variables. A nearly-orthogonal sampling of design space is proposed with good space filling properties to extract maximum useful information about system behavior using much lower number of trial designs. This sampled data is then used as training data for artificial neural network, which will act as a metamodel to represent the time consuming disciplinary analyses. A stage-wise interconnection of separate neural networks is also proposed for trajectory metamodel to offset dimensionality curse of neural networks. Genetic Algorithm performs global optimization by utilizing this metamodel and subsequently sequential quadratic programming performs the local optimization utilizing exact analyses. The performance of proposed methodology is

investigated in this paper for the conceptual design optimization of multistage solid fueled space launch vehicle. The results show excellent approximation of highly non-linear functions using proposed sampling and drastic reduction in overall design optimization time, due to greatly reduced number of exact disciplinary analyses.

SIMULATION-BASED OPTIMIZATION STRATEGY FOR LIQUID FUELED MULTI-STAGE SPACE LAUNCH VEHICLE

Proceedings of the Sixth International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT'05

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Abstract The optimal design of launch vehicles based on liquid rocket engines is critically dependent on ascent trajectories and thrust throttling. Recently many authors have incorporated trajectory optimization at conceptual design level but still have not gauged the potential of using thrust throttling at conceptual design phase. In this study we propose not only the trajectory optimization but also the thrust throttling at the conceptual design phase. This newly formulation problem is solved through hybrid optimization algorithm using Genetic Algorithm as global optimizer and Sequential Quadratic Programming as local optimizer starting from the solution given by Genetic Algorithm. The objective is to find minimum gross launch weight (GLW), optimal trajectory and thrust throttling profile for liquid fueled space launch vehicle (SLV). The improvement in system design using thrust throttling is studied in detail.

Hyper Heuristic Approach for Design and Optimization of Satellite Launch Vehicle

Chinese Journal of Aeronautics, Volume 24, Issue 2, April 2011, Pages 150-163

Amer Farhan RAFIQUE[a], , Linshu HE[a], Ali KAMRAN[b] and Qasim ZEESHAN[a]

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Abstract

Satellite launch vehicle lies at the cross-road of multiple challenging technologies and its design and optimization present a typical example of multidisciplinary design and optimization (MDO) process. The complexity of problem demands highly efficient and effective algorithm that can optimize the design. Hyper heuristic approach (HHA) based on meta-heuristics is applied to the optimization of air launched satellite launch vehicle (ASLV). A non-learning random function (NLRF) is proposed to control low-level meta-heuristics (LLMHs) that increases certainty of global solution, an essential ingredient required in product conceptual design phase of aerospace systems. Comprehensive empirical study is performed to evaluate the performance advantages of proposed approach over popular non-gradient based optimization methods. Design of ASLV encompasses aerodynamics, propulsion, structure, stages layout, mass distribution, and trajectory modules connected by multidisciplinary feasible design approach. This approach

formulates explicit system-level goals and then forwards the design optimization process entirely over to optimizer. This distinctive approach for launch vehicle system design relieves engineers from tedious, iterative task and enables them to improve their component level models. Mass is an impetus on vehicle performance and cost, and so it is considered as the core of vehicle design process. Therefore, gross launch mass is to be minimized in HHA.

Multidisciplinary Design and Optimization of Satellite Launch Vehicle Using Latin Hypercube Design of Experiments

CADDM, 2009, Vol. 19(1)

AMER Farhan Rafique, HE Lin-shu, QASIM Zeeshan (School of Astronautics, Beijing University of Aeronautics and Astronautics, Beijing 100191, China)
Biography: AMER Farhan Rafique (1980-), male, born in Jhelum, Pakistan, PhD Candidate, main research field is multidisciplinary design optimization and launch vehicle design.
afrafique@yahoo.com

Abstract: The design of new Satellite Launch Vehicle (SLV) is of interest, especially when a combination of Solid and Liquid Propulsion is included. Proposed is a conceptual design and optimization technique for multistage Low Earth Orbit (LEO) bound SLV comprising of solid and liquid stages with the use of Genetic Algorithm (GA) as global optimizer. Convergence of GA is improved by introducing initial population based on the Design of Experiments (DOE) Technique. Latin Hypercube Sampling (LHS)-DOE is used for its good space filling properties. LHS is a stratified random procedure that provides an efficient way of sampling variables from their multivariate distributions. In SLV design minimum Gross Lift off Weight (GLOW) concept is traditionally being sought. Since the development costs tend to vary as a function of GLOW, this minimum GLOW is considered as a minimum development cost concept. The design approach is meaningful to initial design sizing purpose for its computational efficiency gives a quick insight into the vehicle performance prior to detailed design.

Simulation-Based Optimization Strategy for Liquid Fueled Multi-stage Space Launch Vehicle

S. Akhtar ; School of Astronautics, Beihang University, Beijing ; He Linshu

The optimal design of launch vehicles based on liquid rocket engines is critically dependent on ascent trajectories and thrust throttling. Recently many authors have incorporated trajectory optimization at conceptual design level but still have not gauged the potential of using thrust throttling at conceptual design phase. In this study we propose not only the trajectory optimization but also the thrust throttling at the conceptual design phase. This newly formulation problem is solved through hybrid optimization algorithm using Genetic Algorithm as global optimizer and Sequential Quadratic Programming as local optimizer starting from the solution given by Genetic Algorithm. The objective is to find minimum gross launch weight (GLW), optimal trajectory and thrust throttling profile for liquid fueled space launch vehicle (SLV). The improvement in system design using thrust throttling is studied in detail.

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Date of Conference: 05-08 Dec. 2005

Multidisciplinary design and optimization of an air launched satellite launch vehicle using a hybrid heuristic search algorithm

Engineering Optimization, Volume 43, Issue 3, 2011, **Page(s):** 359 - 365

A. F. Rafique[a*], L. S. He[a], Q. Zeeshan[a], A. Kamran[a] & K. Nisar[a]

pages 305-328

Abstract

A multidisciplinary design and optimization strategy for a multistage air launched satellite launch vehicle comprising of a solid propulsion system to low earth orbit with the implementation of a hybrid heuristic search algorithm is proposed in this article. The proposed approach integrated the search properties of a genetic algorithm and simulated annealing, thus achieving an optimal solution while satisfying the design objectives and performance constraints. The genetic algorithm identified the feasible region of solutions and simulated annealing exploited the identified feasible region in search of optimality. The proposed methodology coupled with design space reduction allows the designer to explore promising regions of optimality. Modules for mass properties, propulsion characteristics, aerodynamics, and flight dynamics are integrated to produce a high-fidelity model of the vehicle. The objective of this article is to develop a design strategy that more efficiently and effectively facilitates multidisciplinary design analysis and optimization for an air launched satellite launch vehicle.

International Conference, CIS 2005, Xi'an, China, December 15-19, 2005, Proceedings Part I

Support Vector Machine Based Trajectory Metamodel for Conceptual Design of Multi-stage Space Launch Vehicle

- Saqlain Akhtar **Affiliated with** School of Astronautics Beihang University
- , He Linshu **Affiliated with** School of Astronautics Beihang University

Abstract

The design of new Space Launch Vehicle (SLV) involves a full set of disciplines – propulsion, structural sizing, aerodynamics, mission analysis, flight control, stages layout – with strong interaction between each other. Since multidisciplinary design optimization of multistage launch vehicles is a complex and computationally expensive. An efficient Least Square Support Vector Regression (LS-SVR) technique is used for trajectory simulation of multistage space launch vehicle. This newly formulation problem-about 17 parameters, linked to both the architecture

and the command (trajectory optimization), 8 constraints – is solved through hybrid optimization algorithm using Particle Swarm Optimization (PSO) as global optimizer and Sequential Quadratic Programming (SQP) as local optimizer starting from the solution given by (PSO). The objective is to find minimum gross launch weight (GLW) and optimal trajectory during launch maneuvering phase for liquid fueled space launch vehicle (SLV).The computational cost incurred is compared for two cases of conceptual design involving exact trajectory simulation and with Least Square Support Vector Regression based trajectory simulation.

Applied Mechanics and Materials > Information Engineering for Mechanics and... > Optimal Launch Vehicle Configuration from Existing...

September 2013

文章题目:
Optimal Launch Vehicle Configuration from Existing Solid Rocket Motors Using Genetic Algorithm

摘要

This paper describes the optimization approach of a three stage solid propellant launch vehicle configuration from existing solid rocket motors (SRM). The optimal launch vehicle (LV) is capable of delivering a small satellite of 100 kg to a circular low earth orbit of 400, 500 and 600 km altitude. The overall LV configuration and the trajectory profile were optimized simultaneously, thus the existing SRM parameters for first, second and three stages, vertical flight time, launch maneuver variable, maximum angle of attack, coasting time between first and second stage and the second coasting time between second and third stages were optimized. A genetic algorithm global optimization method has been implemented to perform the analysis, the algorithm consider mixed integer continuous variables. The results show that the proposed optimization approach was able to find the optimal solution for all three variants with very acceptable values, and the approach proved to be reliable for conceptual design level.

Design of experiments based variation mode and effect analysis of a conceptual air launched SLV

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- Location: Narvik, Norway

Abstract

Conceptual design stage is where the knowledge about the variation in system is still quite vague and herein we intend to analyze and compare various probable design concepts for Air Launched SLV by the use of basic variation mode and effect analysis. In this paper we present a methodology for the Variation Mode and Effect Analysis using Latin Hypercube Sampling based Design of Experiments for the conceptual Air launched Satellite Launch Vehicle. Variations are induced in the Control Variables based on knowledge and experience. The methodology is used to quantify the effect of Noise Factors on the performance of a conceptual Air Launched SLV. The insertion altitude of the Air Launched SLV is the Key Performance Indicator. Preliminary results of the performance and analysis for the simulated experiments are presented here. The performance of the proposed procedure has been tested and, thus, validated by the Air Launched SLV design problem. The Design of Experiment based Variation mode and effect analysis approach is intended for initial conceptual design purposes, thus, providing an immediate insight to the performance of the system in general and quantification of the sensitivity of the key performance indicator in particular, subject to the variations in noise factors prior to the detailed design phase.

Hyper Heuristic Approach for Design and Optimization of Satellite Launch Vehicle

Chinese Journal of Aeronautics 24 (2011) 150-163

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Abstract: Satellite launch vehicle lies at the cross-road of multiple challenging technologies and its design and optimization present a typical example of multidisciplinary design and optimization (MDO) process. The complexity of problem demands highly efficient and effective algorithm that can optimize the design. Hyper heuristic approach (HHA) based on meta-heuristics is applied to the optimization of air launched satellite launch vehicle (ASLV). A non-learning random function (NLRF) is proposed to control low-level meta-heuristics (LLMHs) that increases certainty of global solution, an essential ingredient required in product conceptual design phase of aerospace systems. Comprehensive empirical study is performed to evaluate the performance advantages of proposed approach over popular non-gradient based optimization methods. Design of ASLV encompasses aerodynamics, propulsion, structure, stages layout, mass distribution, and trajectory modules connected by multidisciplinary feasible design approach. This approach formulates explicit system-level goals and then forwards the design optimization process entirely over to optimizer. This distinctive approach for launch vehicle system design relieves engineers from tedious, iterative task and enables them to improve their component level models. Mass is an impetus on vehicle performance and cost, and so it is considered as the core of vehicle design process. Therefore, gross launch mass is to be minimized in HHA.

Rafique A F, Zeeshan Q, He L S. Conceptual design of a small satellite launch vehicle using hybrid optimization. In: Sivasundaram S. Seventh International Conference on Mathematical

Problems in Engineering, Aerospace and Sciences. Cambridge: Cambridge Scientific Publishers Ltd., 2008; 681-697

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F. M. Villanueva, He Linshu, A. F. Rafique, T. Rahman. Small Launch Vehicle Trajectory Profile Optimization Using Hybrid Algorithm. International Bhurban Conference on Applied Sciences & Technology, IBCAST, Islamabad, Pakistan, January 15 - 19, 2013

Small Launch Vehicle Trajectory Profile Optimization Using Hybrid Algorithm

Proceedings of 2013 10th International Bhurban Conference on Applied Sciences & Technology (IBCAST) 163 Islamabad, Pakistan, 15th - 19th January, 2013

Fredy M. Villanueva*, He Linshu*, Amer Farhan Rafique**, and Tawfiqur Rahman* * School of Astronautics, Beihang University, Beijing 100191, China, ** Mechanical Engineering Department, Mohammad Ali Jinnah University, Islamabad, Pakistan

Abstract- A hybrid optimization approach combining a genetic algorithm (GA) with sequential quadratic programming (SQP) has been used for optimization of the trajectory profile of a three stage solid propellant small launch vehicle configured from existing solid rocket motors. The selected launch vehicle (LV) is capable of delivering a small satellite of 80 kg to a low earth orbit (LEO) of 660 km altitude. This hybrid optimization approach combines the advantage of GA as a global optimizer and complemented with SQP to find the local optimum. The vertical flight time, launch maneuver variable, maximum angle of attack, coasting time between the first and second stage and the second coasting time between the second and third stage were optimized. It is shown that the proposed hybrid optimization approach was able to find the convergence of the optimal solution with very acceptable values.

Rafique, A.F., Linshu, H., Zeeshan, Q., Kamran, A., Multidisciplinary Design of Air Launched Space Launch Vehicle using Simulated Annealing. Lecture Notes in Computer Science 5803 LNAI, pp. 719–726, 2009.

Rafique, A.F., LinShu, H., Kamran, A., Zeeshan, Q., Multidisciplinary Design of Air Launched Satellite Launch Vehicle: Performance Comparison of Heuristic Optimization Methods, Journal of Acta Astronautica, Vol. 67, No. 7-8, pp. 826–844, 2010.

Rafique, A.F., LinShu,H., Zeeshan, Q., Kamran, A., Nisar, K., Multidisciplinary Design and Optimization of an Air Launched Satellite Launch Vehicle using a Hybrid Heuristic Search Algorithm, Journal of Engineering Optimization, 2010, DOI: 10.1080/0305215X.2010.489608

Spacecraft Reactor Research:

Influence of non-ideal gas characteristics on working fluid properties and thermal cycle of space nuclear power generation system

Energy, 2021, Vol. 222, 119881

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Aabstract Space nuclear Closed Brayton Cycle (CBC) power generation system with Helium-xenon gas (HeeXe) as a work fluid has attracted much attention with the development of space technology. The appropriate thermophysical property model of HeeXe is the key to achieve high-precision simulation of CBC power generation system. The thermophysical property model based on virial coefficient was developed and proposed. It was compared with the ideal gas model to clarify the differences and non-ideal gas characteristics of HeeXe. The deviations of HeeXe thermophysical parameters, main cycle parameters under different temperatures and pressures were compared numerically with these models. Based on non-ideal gas properties, a thermodynamic model was developed to analyze the influence of non-ideal gas characteristics on the efficiency of a 3.0 MWth lithium-cold fast reactor power system. The results showed that HeeXe physical parameters deviated from ideal gas characteristics significantly under the molar mass of more than 40 g/mol. Lower temperature (3.0 MPa) tends to make non-ideal gas characteristics on thermophysical parameters more effective. The thermophysical property model with non-ideal gas characteristics improves the system simulation accuracy about 4.91 %. This work can be used as reference for the development, accurate simulation and assessment of space nuclear CBC power generation system.

Radar Related Research:

Conceptual design architecture modeling and simulation for boost phase ballistic missile defense

Computer Aided Design, Drafting and Manufacturing, 18(1), 47– 65.

Zeeshan, Q., Momtaz, M. and Yunfeng, D. (2008)

Adaptive transmit array sidelobe control using FDA-MIMO for tracking in joint radar-communications

Digital Image Processing, 2020, Vol. 97, 102619

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Abstract: In this paper, we present an adaptive closed–loop range-angle dependent sidelobe control using frequency diverse array (FDA) multiple-input multiple-output (MIMO) design for joint radar-communications. The system carries out tracking of the target and the communication

receiver, while transmitting information bits towards the intended communication receiver using a flexible sidelobe control, i.e., controlling the power emitted at a certain angle-range position. The range-angle dependent sidelobe control utilizing an overlapped-FDA generated uncoupled beampattern with the proposed Blackman window based non-uniform frequency offsets enables the communication links to use the same radar spectrum. Moreover, we adaptively design two transmit weight vectors and finally compute a beamspace matrix that facilitates to generate the range-angle dependent beam patterns with a same radar main lobe, but distinct sidelobe levels (in accordance with the binary bit to be transmitted) for the moving target and communication receiver, respectively. Furthermore, we propose a cognitive algorithm to discriminate the target and communication receiver positions. Finally, the information bits can be efficiently detected by the intended communication receiver, merely, due to the power difference in sidelobe levels of the directed range-angle dependent radiated patterns without affecting the radar performance. The improved performance of the proposed design is verified in terms of bit error rate and inherent security for the communication functionality, while target detection, target tracking and parameter estimation are considered for the radar application.

Multisensor-Based Target-Tracking Algorithm with Out-of-Sequence-Measurements in Cluttered Environments

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Abstract: A localization and tracking algorithm for an early-warning tracking system based on the information fusion of Infrared (IR) sensor and Laser Detection and Ranging (LADAR) is proposed. The proposed Kalman filter scheme incorporates Out-of-Sequence Measurements (OOSMs) to address long-range, high-speed incoming targets to be tracked by networked Remote Observation Sites (ROS) in cluttered environments. The Rauch–Tung–Striebel (RTS) fixed lag smoothing algorithm is employed in the proposed technique to further improve tracking accuracy, which, in turn, is used for target profiling and efficient filter initialization at the targeted platform. This efficient initialization increases the probability of target engagement by increasing the distance at which it can be effectively engaged. The increased target engagement range also reduces risk of any damage from debris of the engaged target. Performance of the proposed target localization algorithm with OOSM and RTS smoothing is evaluated in terms of root mean square error (RMSE) for both position and velocity, which accurately depicts the

improved performance of the proposed algorithm in comparison with existing retrodiction-based OOSM filtering algorithms. The effects of assisted target state initialization at the targeted platform are also evaluated in terms of Time to Impact (TTI) and true track retention, which also depict the advantage of the proposed strategy.

Multisensor distributed out-of-sequence-tracks fusion with track origin uncertainty

Aerospace Science and Technology, 2020, Vol. 106, 106226

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Abstract: The increased trend toward multisensor target tracking system is driving an interest for distributed tracks fusion algorithm. In such a system, local tracks formed by each sensor may arrive in the fusion center with temporal out-of-sequence because of different sensor data processing time and random communication delay, moreover, the priori information on the origins of tracks to be fused is usually unknown due to clutter disturbance and presence of multitargets. This paper considers the problem of fusing out-of-sequence tracks (OOSTs) with track origin uncertainty in a distributed fusion setup, and proposes a novel all neighbor fusion-integrated forward prediction fusion and decorrelation (ANF-IFPFD) method. The proposed ANF-IFPFD enumerates and probabilistically evaluates all feasible track-to-track association events, and fuses the central tracks with extracted information purely contributed by the local OOSTs through an information decorrelation process. Furthermore, it enables to operate the false track discrimination (FTD) in the fusion center by using the fused probability of target existence as a track quality measure. Additionally, two implementation configurations of the proposed ANF-IFPFD method are also designed to provide a trade-off between the tracking performance and the system communication bandwidth consumption. Monte Carlo simulations are carried out to validate the superiority of the proposed ANF-IFPFD over the enhanced state-of-art methods, in terms of both tracking performance and also computation-storage requirement. Compared to the configuration without any information feedback, the partial information feedback configuration of the ANF-IFPFD method is verified to deliver intensive improvements for both local tracking and tracks fusing.

A split target detection and tracking algorithm for ballistic missile tracking during the re-entry phase

Defence Technology, 2020, Vol. 16, pp1142-1150

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Abstract: In the re-entry phase of a ballistic missile, decoys can be deployed as a mean to overburden enemy defenses. This results in a single track being split into multiple track-lets. Tracking of these track-lets is a critical task as any miss in the tracking procedure can become a cause of a major threat. The tracking process becomes more complicated in the presence of clutter. The low detection rate is one of the factors that may contribute to increasing the difficulty level in terms of tracking in the cluttered environment. This work introduces a new algorithm for the split event detection and target tracking under the framework of the joint integrated probabilistic data association (JIPDA) algorithm. The proposed algorithm is termed as split event-JIPDA (SE-JIPDA). This work establishes the mathematical foundation for the split target detection and tracking mechanism. The performance analysis is made under different simulation conditions to provide a clear insight into the merits of the proposed algorithm. The performance parameters in these simulations are the root mean square error (RMSE), confirmed true track rate (CTTR) and confirmed split true track rate (CSTTR).

Evaluation of Three Decomposition MDO Algorithms

23rd International Congress of Aerospace Sciences, Toronto, Canada, September, 2002.

Chen, S., Zhang, F., and Khalid, M.

Rocket/Missile Research:

Conceptual Design Trade Offs between Solid and Liquid Propulsion for Optimal Stage Configuration of Satellite Launch Vehicle

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Keywords: Launch Vehicle, Liquid Propulsion, Mission Design, Optimization, Solid Propulsion, Trajectory

Abstract

The foremost criterion in the design of a Satellite Launch Vehicle (SLV) is its performance capability to boost the designated payload to the desired mission orbit; it starts from focusing on the SLV configuration to achieve the velocity requirements (ΔV) for the mission. In this paper we review an analytical approach which is suitable enough for preliminary conceptual design and is used previously to optimize stage configurations for Two Stage to Orbit SLV for Low Earth Orbit (LEO) Missions; we have extended this approach to Three Stage to Orbit SLV and compared different propellant options for the mission. The objective is to minimize the Gross Lift off Weight (GLOW). The primary performance figures of merit were the total inert weight of the SLV and the payload weight that the SLV could lift into LEO, given candidate propulsion systems. The optimization is achieved by configuring the ΔV between stages. A comparison of configurations of single-stage and multi-stage SLVs is made for different propellants. Based upon the optimized stage configurations a comparative performance analysis is made between Liquid and Solid fueled SLV. A 3 degree of freedom trajectory-analysis program is modeled in SIMULINK and used to conduct the performance analysis. Furthermore, a cost analysis is performed on our stage optimized SLVs. The cost estimation relationships (CER) used give us a comparison of development and fabrication costs for the Liquid vs. Solid fueled SLV in man years. The pros and cons of the production, operation ability, performance, responsiveness, logistics, price, shelf life, storage etc of both Solid and Liquid fueled SLVs are discussed. The statistics and data are used from existing or historical (real) SLV stages.

Introduction

It is well known that the aerospace industry is more sensitive to vehicle weight as a primary figure of merit for vehicle designs than any other industry. This is because weight (or mass) is a strong driver on vehicle performance and cost, and so takes a central role in the vehicle design process. In fact, vehicle weight is so important that competitive advantage is often sought largely or exclusively on the basis of having a lighter weight than the competitor. Experience has shown that the cost of a given class of SLV is roughly proportional to the GLOW. The boost phase of an orbital space mission is critical to the design process since the initial weight of the vehicle, which is generally related to its cost, is at its maximum at lift-off. The m_{pay} is a small fraction of the total mass.

Placing an object into orbit is technically demanding and expensive too. A rough rule of thumb is that a modern SLV can deliver into orbit a m_{pay} that is only a few percent of its overall mass. Since the size of the SLV scales with the m_{pay}, there is a tremendous incentive to increase the SLV performance by keeping the mass of SLV as low as possible. We will later discuss that apart from GLOW there are other figures of merit too which strongly dominate and effect the design and performance of a SLV.

Exiting SLVs can be categorized as:

- Any number of stages, inline and/or piggy-back
- Liquid, solid, hybrid, air breathing propulsion systems.
- Mono-propellant, bi-propellant, tri-propellant
- Pump-fed or pressure-fed
- Expendable or recoverable

The research work is in progress for the design of single-stage-to-orbit (SSTO), but no Earth-launched SSTO SLV has ever been constructed. Current orbital launches are either performed by multi-stage fully expendable launchers or by the Space Shuttle which is multi-stage and partially reusable. It is extremely difficult to design a structure which is strong, safe, very light, and economical to build. The problem originally seemed insuperable, and drove all early designers to multistage rockets. In this study multi-stage expendable SLVs are considered for small m_{pay} to LEO.

SLVs are unique forms of transportation since they are the only systems that accelerate continuously throughout their performance envelope. Consequently, velocity is the fundamental measure of performance for any SLV. The ability of any SLV to achieve orbital velocity comes primarily from its propulsion efficiency, with weight and drag acting against it. Available technology constrains the specific impulse (I_{sp}), therefore the trade off has to be made. For each propulsion stage, the amount of work that needs to be done is calculated. This is measured in terms of velocity changes, ΔV. We can estimate the velocity that SLV should provide.

$$\Delta V_{design} = \Delta V_{burnout} + \Delta V_{gravity} + \Delta V_{drag} \qquad (1)$$

Propellant Research:

Design and optimization of slotted tube grain configuration using Simulated Annealing

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Summary. Simulated Annealing is applied in optimization of Slotted tube grain configuration. We propose a CAD based geometry calculation function, to increase calculation accuracy, integrated with internal ballistic model. CAD representation encapsulates all of the geometric entities pertinent to the grain design in a parametric way, allowing manipulation of grain entity (web), performing regression and automating geometrical data calculations. Average thrust is the impetus driver on performance, and so considered as core of grain design process. It is demonstrated with a constrained optimization for Slotted tube grain using simplified internal ballistics model that maximizes average thrust for minimal deviations from neutrality.

Kamran, A. and Guozhu, L., Design and Optimization of 3D Radial Slot Grain Configuration, Chinese Journal of Aeronautics, Vol. 23, No. 4, pp. 409–414, 2010.

An integrated approach for optimization of solid rocket motor

Aerospace Science and Technology, 2011

Ali Kamran ∗ Beijing University of Aeronautics and Astronautics (BUAA), 37 XueYuan Road, HaiDian District, Beijing, 100191, China article info abstract Article history: Received 17 July 2010 Received in revised form 26 February 2011 Accepted 15 March 2011 Available online xxxx

Keywords: Solid rocket motor Multidisciplinary design and optimization Heuristics CAD An integrated approach using hyper-heuristic based on meta-heuristics is applied in optimization of solid rocket motor. We propose a non-learning random function to control low-level meta-heuristics to increase certainty of global solution. A comprehensive empirical study investigates the performance of the proposed algorithm yielding satisfactory results. Design of solid rocket motor becomes an exigent task when accounting for chamber design, nozzle design, ballistic performance calculations as well as grain geometry and regression. CAD modeling overcomes the limitation posed by analytical expression thus increased model fidelity. CAD model allows different sub-systems to be modeled separately that not only prevents feature creation failures but also allows ease in modification of the model. Motor performance is calculated using a simplified ballistic model. Mass is the impetus driver on performance, and so considered as core of solid rocket motor design process. Therefore, we intend to minimize gross mass through hyper-heuristic approach. The approach produced satisfactory results for test case.

A.F. Rafique, H. LinShu, A. Kamran, Q. Zeeshan, Multidisciplinary design of air launched satellite launch vehicle: performance comparison of heuristic optimization methods, Acta Astronautica 67 (7–8) (2010) 826–844

Design and Optimization of 3D Radial Slot Grain Configuration

Chinese Journal of Aeronautics 23(2010) 409-414 www.elsevier.com/locate/cja

Ali Kamran, Liang Guozhu* School of Astronautics, Beijing University of Aeronautics and Astronautics, Beijing 100191, China Received 20 August 2009; accepted 12 March 2010

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Abstract Upper stage solid rocket motors (SRMS) for launch vehicles require a highly efficient propulsion system. Grain design proves to be vital in terms of minimizing inert mass by adopting a high volumetric efficiency with minimum possible sliver. In this article, a methodology has been presented for designing three-dimensional (3D) grain configuration of radial slot for upper stage solid rocket motors. The design process involves parametric modeling of the geometry in computer aided design (CAD) software through dynamic variables that define the complex configuration. Grain burn back is achieved by making new surfaces at each web increment and calculating geometrical properties at each step. Geometrical calculations are based on volume and change-in-volume calculations. Equilibrium pressure method is used to calculate the internal ballistics. Genetic algorithm (GA) has been used as the optimizer because of its robustness and efficient capacity to explore the design space for global optimum solution and eliminate the requirement of an initial guess. Average thrust maximization under design constraints is the objective function.

Nisar K, Liang G Z, Zeeshan Q. A hybrid optimization approach for SRM finocyl grain design. Chinese Journal of Aeronautics 2008; 21(6): 481-487.

A new paradigm for star grain design and optimization

Aircraft Engineering and Aerospace Technology, 2015, Volume 87 Issue 5

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Ali Kamran (Department of Aeronautics and Astronautics, Institution of Space Technology, Islamabad, Pakistan.)
Liang Guozhu (School of Astronautics, Beihang University (BUAA), Beijing, China.)

Abstract

Purpose
The paper aims to extend the knowledge base for design and optimization of Star grain which is well known for its simplicity, reliability and efficiency. Star grain configuration is considered to be among the extensively used configurations for the past 60 years. The unexplored areas of treatment of ballistic constraints, non-neutral trace and freedom from use of generalized design equations and sensitivity analysis of optimum design point are treated in detail to bridge the gap. The foremost purpose is to expand the design domain by considering entire convex Star family under both neutral and non-neutral conditions.

±3-Sigma based design optimization of 3D Finocyl grain

Aerospace Science and Technology 26 (2013) 29–37

Ali Kamran a,∗, Liang Guozhu b, Amer Farhan Rafique a, Qasim Zeeshan a a Institute of Space Technology, Islamabad Highway, Near Rawat Toll Plaza, P.O. Box 44000, Islamabad, Pakistan b Beihang University (BUAA), 37 XueYuan Road, Haidian District, Beijing 100191, China

abstract Article history: Received 27 September 2011 Received in revised form 23 November 2011 Accepted 13 February 2012 Available online 21 February 2012 Keywords: Solid rocket motor Grain design 3-Sigma Robust solution Monte Carlo simulation

A three-sigma (−3 ∼ +3) approach is applied in robust design optimization of Finocyl grain geometry. Grain design becomes an exigent task when accounting for uncertainties in manufacturing processes. Upper stage SRM requires tight control on total impulse and acceleration to ensure safe entry of satellites into orbits. A first order Taylor series is used to calculate solution sensitivity and thus moving toward a robust solution. Motor performance is calculated using a simplified ballistic model with throat erosion considerations. Average thrust and propellant mass are the impetus drivers on performance, and so considered as core of grain design process. Therefore, we intend to maximize them with minimizing the variation in both. Monte Carlo simulation reveals that robust solution proves insensitive to manufacturing uncertainties. The approach produced satisfactory results for test case.

A. Kamran, L. Guozhu, Design and optimization of 3D radial slot grain configuration, Chinese Journal of Aeronautics 23 (4) (2010) 409–414.

A. Kamran, L. Guozhu, Design and optimization of solid rocket motor Finocyl grain using simulated annealing, Journal of Aerospace Power 26 (4) (April 2011) 917–923.

A. Kamran, L. Guozhu, An integrated approach for optimization of solid rocket motor, Aerospace Science and Technology, 2012, Vol. 17(1), pp50-64

Variable-fidelity optimization with design space reduction

Chinese Journal of Aeronautics, 2013, Vol. 26(4), pp841-849

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Abstract: Advanced engineering systems, like aircraft, are defined by tens or even hundreds of design variables. Building an accurate surrogate model for use in such high-dimensional optimization problems is a difficult task owing to the curse of dimensionality. This paper presents a new algorithm to reduce the size of a design space to a smaller region of interest allowing a more accurate surrogate model to be generated. The framework requires a set of models of different physical or numerical fidelities. The low-fidelity (LF) model provides physics-based approximation of the high-fidelity (HF) model at a fraction of the computational cost. It is also instrumental in identifying the small region of interest in the design space that encloses the high-fidelity optimum. A surrogate model is then constructed to match the low-fidelity model to the high-fidelity model in the identified region of interest. The optimization process is managed by an update strategy to prevent convergence to false optima. The algorithm is applied on mathematical problems and a two-dimensional aerodynamic shape optimization problem in a variable-fidelity context. Results obtained are in excellent agreement with high-fidelity results, even with lower-fidelity flow solvers, while showing up to 39% time savings.

Technique to Assess Aging of Propellant Grain

Chinese Journal of Aeronautics, Volume 19, Issue 1, February 2006, Pages 59-64

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Abstract

Physical properties of composite propellants used in solid rocket motors change significantly with age. To predict the margin of safety and to reevaluate the remaining service life, the structural integrity analysis of solid propellant grains of aged rocket motors is pa-formed at various stages of their life span. To have the reliable results from these analyses, it is mandatory to use the current physical properties of the propellant at the time of analysis. Change in physical properties due to aging is more significant at exposed surfaces. Traditional methods of assessing current physical properties may not truly represent the properties of the batch. The paper presents a novel technique to measure the stress strain response at the exposed surface of propellant grain using a miniature testing device. This specially designed device is able to measure the stress response while the propellant surface is compressed at a constant rate. This measured stress strain behavior is then co related with the physical properties measured by routine tensile tests of the similar type of propellant which is aged artificially. It is observed that there exists an excellent correlation between the measured stress values by the sensor and physical properties measured by uni axial tensile test. This nondestructive technique provides properties of propellant grains of all the motors in the batch comprehensively. The technique is safe as well as economical as compared to the traditional methods.

Optimization Based on Convergence Velocity and Reliability for Hydraulic Servo System

Chinese Journal of Aeronautics, Volume 22, Issue 4, August 2009, Pages 407-412

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Abstract

This article presents an optimal hybrid fuzzy proportion integral derivative (HFPID) controller based on combination of proportion integral derivative (PID) and fuzzy controllers, by which the parameters could be evaluated by global optimization either in convergence velocity or in convergence reliability. Focusing on the nonlinear factors of hydraulic servo system, this article takes advantage of PID and fuzzy logic controller integrated with scaling factors to acquire precise tracking performances. To further improve the performances, it provides new developed optimization with rapid convergence to attain reliable approach probability. Focusing on the performance indictors of evolutionary algorithm, this article presents a new technique to predict reliability of the optimization algorithm. Statistics authenticates the effectiveness and robustness of the optimization. Further, many simulation and experimental results indicate that the optimal HFPID could acquire perfect immunity against parametric uncertainties with external disturbance.

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Vitae

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Design and Optimization of 3D Radial Slot Grain Configuration

Chinese Journal of Aeronautics 23(2010) 409-414

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A hybrid optimization approach for SRM finocyl grain design.
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Nisar K, Liang G Z, Zeeshan Q.

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Optimization Based on Convergence Velocity and Reliability for Hydraulic Servo System

Chinese Journal of Aeronautics 22(2009) 407-412

Muhammad Babar Nazir*, Wang Shaoping School of Automation Science and Electrical Engineering, Beijing University of Aeronautics and Astronautics, Beijing 100191, China

Abstract: This article presents an optimal hybrid fuzzy proportion integral derivative (HFPID) controller based on combination of proportion integral derivative (PID) and fuzzy controllers, by which the parameters could be evaluated by global optimization either in convergence velocity or in convergence reliability. Focusing on the nonlinear factors of hydraulic servo system, this article takes advantage of PID and fuzzy logic controller integrated with scaling factors to acquire precise tracking performances. To further improve the performances, it provides new developed optimization with rapid convergence to attain reliable approach probability. Focusing on the performance indicators of evolutionary algorithm, this article presents a new technique to predict reliability of the optimization algorithm. Statistics authenticates the effectiveness and robustness of the optimization. Further, many simulation and experimental results indicate that the optimal HFPID could acquire perfect immunity against parametric uncertainties with external disturbance.

A Hybrid Optimization Approach for SRM FINOCYL Grain Design

Chinese Journal of Aeronautics 21(2008) 481-487

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Abstract This article presents a method to design and optimize 3D FINOCYL grain (FCG) configuration for solid rocket motors (SRMs). The design process of FCG configuration involves mathematical modeling of the geometry and parametric evaluation of various independent geometric variables that define the complex configuration. Virtually infinite combinations of these variables will satisfy the requirements of mass of propellant, thrust, and burning time in addition to satisfying basic needs for volumetric loading fraction and web fraction. In order to ensure the acquisition of the best possible design to be acquired, a sound approach of design and optimization is essentially demanded. To meet this need, a method is introduced to acquire the finest possible performance. A series of computations are carried out to formulate the grain geometry in terms of various combinations of key shapes inclusive of ellipsoid, cone, cylinder, sphere, torus, and inclined plane. A hybrid optimization (HO) technique is established by associating genetic algorithm (GA) for global solution convergence with sequential quadratic programming (SQP) for further local convergence of the solution, thus achieving the final optimal design. A comparison of the optimal design results derived from SQP, GA, and HO algorithms is presented. By using HO technique, the parameter of propellant mass is optimized to the minimum value with the required level of thrust staying within the constrained burning time, nozzle and propellant parameters, and a fixed length and outer diameter of grain.

Khurram N, Liang G Z. Design and comparative study of various two-dimensional grain configurations based on optimization method. Asian Joint Conference on Propulsion and Power (AJCPP). 2008.

Technique to Assess Aging of Propellant Grain

Vol. 19 No. 1 CH INES E JOURNA L O F AERONAU T ICS February 2006

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Abstract: Physical properties of composite propellants used in solid rocket motors change significantly with age. To predict the margin of safety and to reevaluate the remaining service life, the structural integrity analysis of solid propellant g rains of aged rocket motors is performed at various stages of their life span. To have the reliable results from these analyses, it is mandatory to use the current physical proper ties of the propellant at the time of analysis. Change in physical properties due to aging is more significant at exposed surfaces. Traditional methods of assessing current physical properties may not truly represent the properties of the batch. The paper presents a novel technique to measure the stress strain response at the exposed surface of propellant grain using a miniaturetesting device. This specially designed device is able to measure the stress response while the propellant surface is compressed at a constant rate. This measured stress strain behavior is then corelated w ith the physical properties measured by routine tensile tests of the similar type of propellant which is aged artificially. It is observed that there exists an excellent correlation between the measured stress values by the sensor and physical properties measured by uniaxial tensile test. This nondestructive technique provides properties of propellant grains of all the motors in the batch comprehensively. The technique is safe as well as economical as compared to the traditional methods.

Liquid Propellant Research:

Simulation-based optimization and sizing for propulsion system of liquid rocket using genetic algorithm

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Flight vehicle conceptual design appears to be a promising area for application of the genetic algorithm as an approach to help automate part of the design process. This computational research effort strives to develop a propulsion system design strategy for liquid rocket to achieve minimum take-off mass, satisfying the mission range under the constraint of axial overload. The methods by which this process is accomplished by using genetic algorithm (GA) as optimizer are outlined in this paper. Convergence of GA is improved by introducing initial population based on design of experiments technique.

Emerging Technologies, 2005. Proceedings of the IEEE Symposium on, Date of Conference: 17-18 Sept. 2005, Page(s): 376 - 381

Optimization and Sizing for Propulsion System of Liquid Rocket Using Genetic Algorithm

Chinese Journal of Aeronautics 20(2007)40-46 www.elsevier.com/locate/cj

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Abstract Flight vehicle conceptual design appears to be a promising area for application of the Genetic Algorithm (GA) as an approach to help to automate part of the design process. This computational research effort strives to develop a propulsion system design strategy for liquid rocket to optimize take-off mass, satisfying the mission range under the constraint of axial overload. The method by which this process is accomplished by using GA as optimizer is outlined in this paper. Convergence of GA is improved by introducing initial population based on Design of Experiments Technique.

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Ground Based Interceptors:

Meta-heuristic approach for the conceptual design and optimization of multistage interceptor

18th World IMACS / MODSIM Congress, Cairns, Australia 13-17 July 2009 http://mssanz.org.au/modsim09

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Abstract: The design of a missile system capable of intercepting fast moving target(s) is a complex problem that must balance competing objectives and constraints. It involves teams of specialists working separately in their specialized design domains (such as propulsion, aerodynamics, guidance etc), but are also coordinated through a system level set of design requirements such as physical size or weight. This type of segmented design process requires rigorous iterations to ensure that the missile sub-systems are compatible with each other while

still meeting the mission specifications. Therefore the need arises for a Multidisciplinary Design Optimization (MDO) approach that can control the design domains concurrently and configure an optimum design within the set design limits and constraints.

Khurram Nisar, Liang Guozhu, Qasim Zeeshan. “A Hybrid Optimization Approach for SRM Finocyl Grain Design”. Chinese Journal of Aeronautics, Vol 21(5), pp 481~487,Dec 2008

Multidisciplinary Design and Optimization of Multistage Ground-launched Boost Phase Interceptor Using Hybrid Search Algorithm

Chinese Journal of Aeronautics 23(2010) 170-178 www.elsevier.com/locate/cja

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Abstract This article proposes a multidisciplinary design and optimization (MDO) strategy for the conceptual design of a multistage ground-based interceptor (GBI) using hybrid optimization

algorithm, which associates genetic algorithm (GA) as a global optimizer with sequential quadratic programming (SQP) as a local optimizer. The interceptor is comprised of a three-stage solid propulsion system for an exoatmospheric boost phase intercept (BPI). The interceptor's duty is to deliver a kinetic kill vehicle (KKV) to the optimal position in space to accomplish the mission of intercept. The modules for propulsion, aerodynamics, mass properties and flight dynamics are integrated to produce a high fidelity model of the entire vehicle. The propulsion module comprises of solid rocket motor (SRM) grain design, nozzle geometry design and performance prediction analysis. Internal ballistics and performance prediction parameters are calculated by using lumped parameter method. The design objective is to minimize the gross lift off mass (GLOM) of the interceptor under the mission constraints and performance objectives. The proposed design and optimization methodology provide designers with an efficient and powerful approach in computation during designing interceptor systems.

Q. Zeeshan, D. Yunfeng, A. Raique, K. Nisar, A. Kamran. Metaheuristic Approach for the Conceptual Design and Optimization of Multistage Interceptor, 18th World IMACS/MODSIM Congress, Cains, Australia, 13 -17 July 2009.

Multidisciplinary Robust Design and Optimization of Multistage Boost Phase Interceptor

51th AIAA/ASME/ASCE/ASC Structures, Structural Dynamics and Materials Conference, April 12-15, 2010, Olranda, Florida

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Abstract:This paper presents Robust Design Method (RDM) for the conceptual design of a multistage boost phase interceptor to obtain an optimum system configuration insensitive to uncertainties in the form of design variable variations. The mission of Ground Based Interceptor is to deliver Kinetic Kill Vehicle to an optimal position in space to allow it to complete the intercept. RDM is implemented using First Order Orthogonal Design Matrix (FOODM) to calculate the worst-case variation which is then utilized to evaluate the mean and variance of a system output. Latin Hypercube Sampling (LHS) is used for its good space filling properties to extract maximum useful information about 'mean' of quality function. The performance of Robust Design is compared with the Optimal Design. Genetic Algorithm (GA) is used as optimizer to search the design space for optimal and robust solution. Real/exact simulation analyses are used instead of surrogate models. To compare the robustness of the solutions obtained, a sensitivity analysis is performed using Monte Carlo simulation runs. The results indicate that the proposed method can find a robust configuration without compromising the performance objectives and design constraints.

Multidisciplinary Design and Optimization of Multistage Ground-launched Boost Phase Interceptor Using Hybrid Search Algorithm

Chinese Journal of Aeronautics 23(2010) 170-178

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Abstract: This article proposes a multidisciplinary design and optimization (MDO) strategy for the conceptual design of a multistage ground-based interceptor (GBI) using hybrid optimization algorithm, which associates genetic algorithm (GA) as a global optimizer with sequential quadratic programming (SQP) as a local optimizer. The interceptor is comprised of a three-stage solid propulsion system for an exoatmospheric boost phase intercept (BPI). The interceptor's duty is to deliver a kinetic kill vehicle (KKV) to the optimal position in space to accomplish the mission of intercept. The modules for propulsion, aerodynamics, mass properties and flight dynamics are integrated to produce a high fidelity model of the entire vehicle. The propulsion module comprises of solid rocket motor (SRM) grain design, nozzle geometry design and performance prediction analysis. Internal ballistics and performance prediction parameters are calculated by using lumped parameter method. The design objective is to minimize the gross lift off mass (GLOM) of the interceptor under the mission constraints and performance objectives. The proposed design and optimization methodology provide designers with an efficient and powerful approach in computation during designing interceptor systems.

《计算机辅助绘图设计与制造(英文版)》 2008-01

Conceptual Design Architecture Modeling and Simulation for Boost Phase Ballistic Missile Defense

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The design review, simulation and validation of a Conceptual Design Architecture (CDA) for Ballistic Missile Defense (BMD) are presented. An intercept system that contains a Ground Based Interceptor (GBI) and its guidance sensors (both radar and infrared) are simulated. 3D model using MATLAB is developed for a multistage target with ascent phase acceleration profile that depends on total mass, propellant mass and the specific impulse in the gravity field. The radar cross section (RCS) and infrared radiation (IR) of the target structure is estimated as a function of the flight profile. The Kill Vehicle (KV) design is examined as a function of the KV mass, acceleration capability, aimpoint offset and impact energy to destroy the target. The aim of the CDA is to: detect the launch of a threat ballistic missile, determine whether the detected object is a threat,define the characteristics of the threat ballistic missile, develop a firing solution to negate the threat ballistic missile, engage the threat ballistic missile, and assess the effectiveness for ballistic missile intercept. The architecture is modeled in Matlab.

Support Vector Regression-driven Multidisciplinary Design Optimization of Multistage Ground Based Interceptor

AIAA Modeling and Simulation Technologies Conference 10 - 13 August 2009, Chicago, Illinois

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Abstract: In this paper we propose meta-model based design and optimization strategy for multistage ground based interceptor comprising of three stage solid propulsion system for an exo-atmospheric boost phase intercept. An efficient Least Square Support Vector Regression technique is used to approximate the current problem. The mission of Ground Based Interceptor is to deliver Kinetic Kill Vehicle to an optimal position in space to allow it to complete the intercept. The modules for propulsion characteristics, mass properties and flight dynamics have been integrated to produce a high fidelity model of the entire vehicle. For the present effort, the design objective is to minimize the Gross Lift off Mass of the ground based interceptor under the mission constraints of miss distance, intercept time, lateral divert, velocity at intercept, g-loads and stage configuration requirements as Solid Rocket Motor envelope constraints which comprise of length to diameter ratios, nozzle expansion ratios, propellant burn rates and grain geometry constraints like web fraction, volumetric loading efficiency etc. Though, the optimization results and performance are to be considered as preliminary (proof-of-concept) only, but they can be compared to existing systems and used for conceptual design of ground

based interceptors. The proposed design and optimization methodology provides the designer with a time efficient and powerful approach for the design of interceptor systems.

Hypersonic/Boost Glide Research:

Thesis:

Numerical Simulation of High Speed Vehicle using High Resolution, High-Order, and Low Dissipative Scheme.

Kamran R. Q.. PhD thesis, Beihang University, Beijing, China, 2008

Trajectory optimisation for a rocket-assisted hypersonic boost-glide vehicle

The Aeronautical Journal, Volume 121 Issue 1238

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Abstract

In this work, trajectory optimisation has been performed for a wing-body rocket assisted vehicle to compute the bestset of performance parameters including burn-out angle, angle-of-attack, bank-angle and throttle command that would result in optimal down-range and cross-range performance of the re-entry vehicle. An hp-adaptive Pseudospectral method has been used for the optimisation by combining the launch and rocket rocket-assisted re-entry stages. The purpose of the research is to compute optimal burn-out condition, angle-of-attack, bank-angle and optimal thrust segments that would maximise the down-range and cross-range performance of the hypersonic boost glide vehicle, under constrained heat rate environments. The variation of down-range/cross-range performance of rocket rocket-assisted hypersonic boost glide vehicle with bounds on diminishing heat rate has also been computed.

Boundary Conditions for Skip Entry Trajectory

Proceedings of 2014 11th International Bhurban Conference on Applied Sciences & Technology (IBCAST) Islamabad, Pakistan, 14th – 18th January, 2014

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Abstract— Precise landing, range modification and high speed control are the main features of the skip entry trajectory. To fulfill these features some boundary conditions are needed to be known, pull-up and exit point are one of them. These have the applications in guidance, control and telecommunication. Feasibility analysis for the calculations of parameters at these conditions using the analytical method instead of solving the complete 3DOF or 6DOF equation of motion is done. For a given entry flight path angle and lift to drag ratios the pull-up altitude, velocity, aerodynamic deceleration as a pull-up parameters and exit velocity as an exit parameters are calculated. Although the maximum deceleration occurs near pull-up altitude and in the literature sometimes they are treated as a same boundary condition. The difference between these two conditions is also analyzed. Using the assumption of planer entry the 3DOF equation of motion is simulated for the purpose of comparison.

Design and Simulation of Range Enhancement of Reentry Vehicle

Khurram Shahzad; Hu Weiduo

Abstract:
Trajectory dispersion for the reusable launch vehicle during the entry interface and after entering in the Earth atmosphere is needed to be corrected. Normally the Terminal Area Energy Management phase of the reentry is the appropriate phase to accomplish the above mentioned task. To do these corrections, range maximization is required during this phase so that guidance and control have enough time to adjust these dispersions. For the winged body reusable launch vehicle with sufficient lift to drag ratio, the range may be enhanced after the entry by exploiting its lift to drag ratio. Various optimization algorithms are proposed to achieve the stated maximization objective. Quasi equilibrium glide solution for equation of motion at constant dynamic pressure is proposed in this research. A reference trajectory based on the mentioned solution is generated includes reference values of angle of attack and flight path angle against given velocity and altitude. Angle of attack is used as a regulating variable. For tracking, an error signal based on the negative feedback is generated. This error signal used as a correction factor which is in fact difference in reference value of quasi equilibrium glide solution and actual value of the flight path angle. Variable gains are used for the trajectory tracking via a feedback controller. Simulations results using optimization technique and maximum lift to drag ratio are also generated for the purpose of comparison. Simulated results exhibited that the proposed scheme is a good candidate in achieving the desired objective of range maximization with added benefit of smooth control signal and flight vehicle safety.

Published in: 2019 16th International Bhurban Conference on Applied Sciences and Technology (IBCAST)

Vehicle performance tradeoff study for a small size lifting re-entry vehicle

S. Tauqeer ul Islam Rizvi; He Linshu; Naseemullah

Abstract:
A wing-body re-entry vehicle has higher lift-to-drag ratio and enhances the down-range and the cross range of a ballistic vehicle. In the present study, trade-off analysis has been carried out between vehicle performance and flight parameters with variation in burn out angle at suborbital speeds. The vehicle during its re-entry flight is subjected to extreme heat rate and very high dynamic pressures. The re-entry range is maximized for shallow entry angles. Lowering the re-entry angle implies lowering the flight path angle at the burn out point. This results in increase in re-entry range and reduction of free flight range. These two parameters affect the overall range of the vehicle. Longer flight times at shallow re-entry angles also result in an increase of the total heat load. The burn-out angle also affects the g-load required to initiate the initial skip. This paper discusses the sensitivity of total heat load, maximum normal acceleration, range and the flight time once the re-entry trajectory is optimized for maximum down range subject to maximum dynamic pressure constraint of 350 KPa and 3 MW/m^2 of heat rate limit for a range of burn-out velocities and burn-out angles. All trajectories within the matrix have been optimized for maximum down range/cross range using hp-adaptive pseudospectral method. The optimal angle-of-attack and bank angle control deflections have also been discussed. It has been found that for a boost-glide wing-body vehicle, the range advantage is of more than 35 percent as compared to bi-conic re-entry vehicle. Near optimal down range is obtained at burn-out angle of approximately 15 degree. The g-loads and angle-of-attack trim control requirements remain within limits. Cross-ranges of the order of 800 to 2000 km can be obtained with in the medium to intermediate range using wing-body re-entry vehicle design.

Proceedings of 2013 10th International Bhurban Conference on Applied Sciences & Technology (IBCAST)

- **Trajectory optimization study of a lifting body re-entry vehicle for medium to intermediate range applications**

AIP Conference Proceedings **1493**, 782 (2012); https://doi.org/10.1063/1.4765577

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ABSTRACT

A numerical optimization study of lifting body re-entry vehicles is presented for nominal as well as shallow entry conditions for Medium and Intermediate Range applications. Due to the stringent requirement of a high degree of accuracy for conventional vehicles, lifting re-entry can be used to attain the impact at the desired terminal flight path angle and speed and thus can potentially improve accuracy of the re-entry vehicle. The re-entry of a medium range and

intermediate range vehicles is characterized by very high negative flight path angle and low re-entry speed as compared to a maneuverable re-entry vehicle or a common aero vehicle intended for an intercontinental range. Highly negative flight path angles at the re-entry impose high dynamic pressure as well as heat loads on the vehicle. The trajectory studies are carried out to maximize the cross range of the re-entry vehicle while imposing a maximum dynamic pressure constraint of 350 KPa with a 3 MW/m^2 heat rate limit. The maximum normal acceleration and the total heat load experienced by the vehicle at the stagnation point during the maneuver have been computed for the vehicle for possible future conceptual design studies. It has been found that cross range capability of up to 35 km can be achieved with a lifting-body design within the heat rate and the dynamic pressure boundary at normal entry conditions. For shallow entry angle of −20 degree and intermediate ranges a cross range capability of up to 250 km can be attained for a lifting body design with less than 10 percent loss in overall range. The normal acceleration also remains within limits. The lifting-body results have also been compared with wing-body results at shallow entry condition. An hp-adaptive pseudo-spectral method has been used for constrained trajectory optimization.

Trajectory optimisation for a rocket-assisted hypersonic boost-glide vehicle

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ABSTRACT In this work, trajectory optimisation has been performed for a wing-body rocket assisted vehicle to compute the bestset of performance parameters including burn-out angle, angleof-attack, bank-angle and throttle command that would result in optimal down-range and cross-range performance of the re-entry vehicle. An hp-adaptive Pseudospectral method has been used for the optimisation by combining the launch and rocket rocket-assisted re-entry stages. The purpose of the research is to compute optimal burn-out condition, angle-of-attack, bank-angle and optimal thrust segments that would maximise the down-range and cross-range performance of the hypersonic boost glide vehicle, under constrained heat rate environments. The variation of down-range/cross-range performance of rocket rocket-assisted hypersonic boost glide vehicle with bounds on diminishing heat rate has also been computed.

Rizvi, S.T.I., He, L. and Xu, D. Optimal trajectory analysis of hypersonic boost-glide waverider with heat load constraint, Airc Engineering and Aerospace Technology, 2015, 87, pp 67-78.

Rizvi, S.T.I., He, L. and Xu, D. Optimal trajectory and heat load analysis of different shape reentry vehicles for medium range application, DefenceTechnology, 2015, 11, pp 450-361.

Optimal trajectory analysis of hypersonic boost-glide waverider with heat load constraint

Aircarft Engineering and Aerospace Technology, November 2013

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Abstract Purpose – The purpose of the paper is to study the variation of optimal burnout angle at the end of the ascent phase and the optimal control deflection during the glide phase, that would maximize the downrange performance of a hypersonic boost-glide waverider, with variation in heat rate and integrated heat load limit. Design/methodology/approach – The approach used is to model the boost phase so as to optimize the burnout conditions. The nonlinear, multiphase, constraint optimal control problem is solved using an hp-adaptive pseudospectral method. Findings – The constraint heat load results for the waverider configuration reveal that the integrated heat load can be reduced by more than half with only 10 per cent penalty in the overall downrange of the hypersonic boost-glide vehicle, within a burnout speed range of 3.7 to 4.3 km/s. The angle-of-attack trim control requirements increase with stringent heat rate and integrated heat load bounds. The normal acceleration remains within limits. Practical implications – The trajectory results imply lower thermal protection system weight because of reduced heat load trajectory profile and therefore lower thermal protection system cost.

Trajectory optimisation for a rocket-assisted hypersonic boost-glide vehicle

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ABSTRACT In this work, trajectory optimisation has been performed for a wing-body rocket assisted vehicle to compute the bestset of performance parameters including burn-out angle, angleof-attack, bank-angle and throttle command that would result in optimal down-range and cross-range performance of the re-entry vehicle. An hp-adaptive Pseudospectral method has been used for the optimisation by combining the launch and rocket rocket-assisted re-entry stages. The purpose of the research is to compute optimal burn-out condition, angle-of-attack, bank-angle and optimal thrust segments that would maximise the down-range and cross-range performance of the hypersonic boost glide vehicle, under constrained heat rate environments. The variation of down-range/cross-range performance of rocket rocket-assisted hypersonic boost glide vehicle with bounds on diminishing heat rate has also been computed.

Shape Optimization of the Cross-Section for Noncircular Hypersonic Missile Forebody

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In the hypersonic regime, noncircular missiles have attracted significant attention from researchers. The paper first summarizes the development and present situation of the noncircular missiles at home and abroad. Previous research found that the cross-section shape of missiles has a direct influence on the aerodynamics performance. To find the best cross-section shape in terms of lift-drag-ratio, an efficient and robust shape optimization framework is developed.

Class/shape function transformation (CST) method and power-law curve are introduced to complete the parametric modeling of the noncircular missile. The evolutionary algorithm has been utilized to improve the optimization efficiency. A combination of script and journal files is written to automate the CAD loft, mesh generation, and CFD simulations process. Finally, the forebody section of a missile body is chosen as an example to deliver the whole optimization steps. The optimization results show that the lift-to-drag ratio increases from 1.8 to 2.4 when the hypersonic missile forebody cruises at the design condition. The results also demonstrate that the optimized configuration has a better aerodynamic performance than the original one over a wide speed range from Mach 2 to 8 and a wide attack of angle range from 0 to 30.

Fuzzy stable inversion-based output tracking for nonlinear non-minimum phase system and application to FAHVs

Journal of the Franklin Institute, 2015, Vol. 352, pp5529-5550

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Abstract In this paper, a novel fuzzy stable inversion-based output tracking control for multi-input multi-output (MIMO) nonlinear non-minimum phase system is investigated. By applying input/output linearization, the nonlinear system is transformed into a standard form. By applying T–S fuzzy based non-causal inversion approach, more reliable ideal internal dynamics (IID) of the nonlinear system are obtained. The output tracking problem is transformed into a state tracking one, then the T–S fuzzy model technology, which can get a more practical description than simple linearization, is utilized to approach the complex nonlinearity of the internal dynamics. A fuzzy controller design method is proposed for the constructed T–S fuzzy model. The proposed method can improve the control performance of the stable inversion based method, and can be easily solved by standard numerical algorithms. Moreover, the proposed control scheme is applied to solve the output tracking problem of flexible air-breathing hypersonic vehicles (FAHVs).

Optimal trajectory analysis of hypersonic boost-glide waverider with heat load constraint

Aircraft Engineering and Aerospace Technology, 2015, Volume 87 Issue 1

S. Tauqeer ul Islam Rizvi , He Linshu , Xu Dajun
Aircraft Engineering and Aerospace Technology

Abstract

Purpose

The purpose of the paper is to study the variation of optimal burnout angle at the end of the ascent phase and the optimal control deflection during the glide phase, that would maximize the downrange performance of a hypersonic boost-glide waverider, with variation in heat rate and integrated heat load limit.

Design/methodology/approach

The approach used is to model the boost phase so as to optimize the burnout conditions. The nonlinear, multiphase, constraint optimal control problem is solved using an hp-adaptive pseudospectral method.

Findings

The constraint heat load results for the waverider configuration reveal that the integrated heat load can be reduced by more than half with only 10 per cent penalty in the overall downrange of the hypersonic boost-glide vehicle, within a burnout speed range of 3.7 to 4.3 km/s. The angle-of-attack trim control requirements increase with stringent heat rate and integrated heat load bounds. The normal acceleration remains within limits.

Trajectory optimisation for a rocket-assisted hypersonic boost-glide vehicle

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ABSTRACT: In this work, trajectory optimisation has been performed for a wing-body rocket assisted vehicle to compute the bestset of performance parameters including burn-out angle, angleof-attack, bank-angle and throttle command that would result in optimal down-range and cross-range performance of the re-entry vehicle. An hp-adaptive Pseudospectral method has been used for the optimisation by combining the launch and rocket rocket-assisted re-entry stages. The purpose of the research is to compute optimal burn-out condition, angle-of-attack, bank-angle and optimal thrust segments that would maximise the down-range and cross-range performance of the hypersonic boost glide vehicle, under constrained heat rate environments. The variation of down-range/cross-range performance of rocket rocket-assisted hypersonic boost glide vehicle with bounds on diminishing heat rate has also been computed.

Radiation effects on MHD stagnation point flow of nanofluid towards a stretching surface with convective boundary condition

Chinese Society of Aeronautic, 2013, Vol. 26(6), pp1389-1397

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Abstract: The aim of the present paper is to study the numerical solutions of the steady MHD two dimensional stagnation point flow of an incompressible nanofluid towards a stretching cylinder. The effects of radiation and convective boundary condition are also taken into account. The model used for the nanofluid incorporates the effects of Brownian motion and thermophoresis. The resulting nonlinear momentum, energy and nanoparticle equations are simplified using similarity transformations. Numerical solutions have been obtained for the velocity, temperature and nanoparticle fraction profiles. The influence of physical parameters on the velocity, temperature, nanoparticle fraction, rates of heat transfer and nanoparticle fraction are shown graphically.

Multidisciplinary optimization of transonic wing using evolutionary algorithm

Applied Sciences and Technology (IBCAST), 2013 10th International Bhurban Conference on

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Abstract: This paper presents the importance of multidisciplinary optimization and its promising results. Evolutionary algorithm is applied which takes into account the aerodynamics and structure of transonic wing. Some classical and widely accepted principles are applied to predict the performance of the wing. Aerodynamic module calculates the induced drag of the wing using multiple lifting line theory. The friction/form drag is calculated by wetted area and using the prediction of skin friction models and form-factor estimation. Total drag is then calculated by summing the induced drag, friction drag and the wave drag, from Korn equation. To estimate the bending material weight, wing is modeled as double-plate wing box. Trade-off between minimum drag and minimum weight is studied. The dependency of the design space on specific wing parameters has also been studied. A significant improvement in the performance of a transonic transport aircraft wing can be achieved using the multidisciplinary optimization technique.

Vehicle performance tradeoff study for a small size lifting re-entry vehicle

Applied Sciences and Technology (IBCAST), 2013 10th International Bhurban Conference on

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Abstract: A wing-body re-entry vehicle has higher lift-to-drag ratio and enhances the down-range and the cross range of a ballistic vehicle. In the present study, trade-off analysis has been carried out between vehicle performance and flight parameters with variation in burn out angle at suborbital speeds. The vehicle during its re-entry flight is subjected to extreme heat rate and very

high dynamic pressures. The re-entry range is maximized for shallow entry angles. Lowering the re-entry angle implies lowering the flight path angle at the burn out point. This results in increase in re-entry range and reduction of free flight range. These two parameters affect the overall range of the vehicle. Longer flight times at shallow re-entry angles also result in an increase of the total heat load. The burn-out angle also affects the g-load required to initiate the initial skip. This paper discusses the sensitivity of total heat load, maximum normal acceleration, range and the flight time once the re-entry trajectory is optimized for maximum down range subject to maximum dynamic pressure constraint of 350 KPa and 3 MW/m^2 of heat rate limit for a range of burn-out velocities and burn-out angles. All trajectories within the matrix have been optimized for maximum down range/cross range using hp-adaptive pseudospectral method. The optimal angle-of-attack and bank angle control deflections have also been discussed. It has been found that for a boost-glide wing-body vehicle, the range advantage is of more than 35 percent as compared to bi-conic re-entry vehicle. Near optimal down range is obtained at burn-out angle of approximately 15 degree. The g-loads and angle-of-attack trim control requirements remain within limits. Cross-ranges of the order of 800 to 2000 km can be obtained with in the medium to intermediate range using wing-body re-entry vehicle design.

Adaptive integral dynamic surface control of a hypersonic flight vehicle

International Journal of Systems Science, Volume 46, 2015 - Issue 10, Pages 1717-1728

Waseem Aslam Butt, Lin Yan & Kendrick Amezquita S.

Abstract: In this article, non-linear adaptive dynamic surface air speed and flight path angle control designs are presented for the longitudinal dynamics of a flexible hypersonic flight vehicle. The tracking performance of the control design is enhanced by introducing a novel integral term that caters to avoiding a large initial control signal. To ensure feasibility, the design scheme incorporates magnitude and rate constraints on the actuator commands. The uncertain non-linear functions are approximated by an efficient use of the neural networks to reduce the computational load. A detailed stability analysis shows that all closed-loop signals are uniformly ultimately bounded and the <img L ∞ L∞ tracking performance is guaranteed. The robustness of the design scheme is verified through numerical simulations of the flexible flight vehicle model.

Author information

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Waseem Aslam Butt received his BE degree in electrical engineering from the College of Electrical and Mechanical Engineering, Rawalpindi, Pakistan in 1993, his MSc degree in control systems with distinction from the University of Sheffield, UK, in 2004 and his PhD degree in control theory and control engineering from the Beijing University of Aeronautics and Astronautics (BUAA), Beijing, China, in 2012. He is a recipient of Laverick–Webster–Hewitt Prize (2003/2004) and he has also been awarded with the Distinguished Foreign Students Scholarship award of Beijing Municipal Government and BUAA, China (2011). He is affiliated with the Department of Electrical Engineering, College of Electrical and Mechanical Engineering, NUST, Rawalpindi, Pakistan. His research interests include robust and adaptive control of flight vehicles.

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Simulation of Flow Separation and Wake

Proceedings of the International Conference on Mechanical Engineering and Mechatronics
Ottawa, Ontario, Canada, 16-18 August 2012 Paper No. 86

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Abstract - Computational fluid-dynamics results are presented to show the flowfield around a blunted cone–flare and cone cylinder body in hypersonic flow. This problem is of particular interest since it features most of the aspects of the hypersonic flow around planetary entry vehicles. The region between the cone and the flare and wake is particularly critical with respect to the evaluation of the surface heat flux. Indeed, flow separation is induced by the shock wave boundary layer interaction, with subsequent flow reattachment, that can dramatically enhance the surface heat transfer and skin friction. The exact determination of the extension of the recirculation zone is a particularly delicate task for numerical codes. In this paper CFD analysis of cone cylinder with wake region is simulated to capture the flow separation in wake region and boundary layers. The base drag is a significant portion of total drag of vehicle so it is simulated well in this paper.

Aeroelastic Analysis of High Aspect Ratio Wing in Subsonic Flow

Proceedings of 2013 10th International Bhurban Conference on Applied Sciences & Technology (IBCAST) Islamabad, Pakistan, 15th - 19th January, 2013

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Abstract-High altitude long endurance (HALE) UA Vs have very flexible wing because of mission requirements. High lifts to drag ratio and more surveillance time in air requirements make their structure highly flexible and large tip deflections can occur which can be as large as 30% of wing semi span. Linear theory fails to accurately analyze such deformation and the changes in the structural and aerodynamic characteristics of the wing accompanying such deformation. Low aspect ratio wing and stiff structures can be best simulated by normal modes in aeroelastic analysis. However high aspect ratio restricts the use of reduce order model based on linear normal modes in aeroelastic analysis. The reason not to use the linear elastic normal modes in high AR wings is the stiffening effects because of large deflections. These effects cause the normal modes to fail as a good basis set. In such situation one needs to use the modified basis function. The computational model used in this work consists of a modified modal based reduced order nonlinear structural dynamics model coupled to a ZONA6's lifting surface method which is a higher-order panel method. Using modified modal basis, geometrical nonlinearities has been captured very well. Aeroelastic analyses agree well with the published data.

Boundary conditions for skip entry trajectory

Applied Sciences and Technology (IBCAST), 2014 11th International Bhurban Conference on

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Abstract: Precise landing, range modification and high speed control are the main features of the skip entry trajectory. To fulfill these features some boundary conditions are needed to be known, pull-up and exit point are one of them. These have the applications in guidance, control and telecommunication. Feasibility analysis for the calculations of parameters at these conditions using the analytical method instead of solving the complete 3DOF or 6DOF equation of motion is done. For a given entry flight path angle and lift to drag ratios the pull-up altitude, velocity, aerodynamic deceleration as a pull-up parameters and exit velocity as an exit parameters are calculated. Although the maximum deceleration occurs near pull-up altitude and in the literature sometimes they are treated as a same boundary condition. The difference between these two conditions is also analyzed. Using the assumption of planer entry the 3DOF equation of motion is simulated for the purpose of comparison.

Zahir S and Ye Z 2006 **Computational Aerodynamic Interaction of a Short Protuberance /Lateral Plate on Blunted Cone Configurations in Hypersonic Flow** AIAA-2006-3172 (24th Applied Aerodynamics Conference) (CA, USA).

Zahir S and Ye Z Hypersonic 2007 **Flow Interaction of Pitched Plates on Blunted Cone at Incidence** (Inter Journal of Mathematical Models and Methods in Applied Sciences) Vol.1, Issue3, pp: 133–136.

A difference-fractional FOM decision method for down selection of hypersonic compression system configurations,

Aerospace Science and Technology, vol. 27, pp. 147-155, 2013

A.Sarosh, C. Shi-Ming, and D. Yun-Feng

An Aerothermodynamic Design Approach for Scramjet Combustors and Comparative Performance of Low Efficiency Systems

Applied Mechanics and Materials, vol. 110, pp. 4652-4660, 2012

A. Sarosh, D. Y. Feng, and M. Adnan

Optimal trajectory and heat load analysis of different shape lifting reentry vehicles for medium range application

Defence Technology, 2015, Vol. 11, pp350-361

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Abstract The objective of the paper is to compute the optimal burn-out conditions and control requirements that would result in maximum down-range/ cross-range performance of a waverider type hypersonic boost-glide (HBG) vehicle within the medium and intermediate ranges, and compare its performance with the performances of wing-body and lifting-body vehicles vis-a-vis the g-load and the integrated heat load experienced by vehicles for the medium-sized launch vehicle under study. Trajectory optimization studies were carried out by considering the heat rate and dynamic pressure constraints. The trajectory optimization problem is modeled as a nonlinear, multiphase, constraint optimal control problem and is solved using a hp-adaptive pseudospectral method. Detail modeling aspects of mass, aerodynamics and aerothermodynamics for the launch and glide vehicles have been discussed. It was found that the optimal burn-out angles for waverider and wing-body configurations are approximately 5 and 14.8, respectively, for maximum down-range performance under the constraint heat rate environment. The down-range and cross-range performance of HBG waverider configuration is nearly 1.3 and 2 times that of wing-body configuration respectively. The integrated heat load experienced by the HBG waverider was found to be approximately an order of magnitude higher than that of a lifting-body configuration and 5 times that of a wing-body configuration. The footprints and corresponding heat loads and control requirements for the three types of glide vehicles are discussed for the medium range launch vehicle under consideration.

Optimal trajectory analysis of hypersonic boost-glide waverider with heat constraint.
Aircraft Engineering and Aerospace Technology 2015;87(1):67e78.
http://dx.doi.org/10.1108/AEAT-04-2013-0079. Rizvi STI, Linshu H, Dajun X.

Vehicle performance tradeoff study of small size lifting re-entry vehicle.
10th international Bhurban conference on applied sciences & technology. Islamabad: National Centre for Physics, Quaid-i-Azam University; 2013. p. 154e62. http://
dx.doi.org/10.1109/IBCAST.2013.6512149. IEEE.
Rizvi STI, Linshu H, Nasimullah.

Optimal trajectory analysis of hypersonic boost-glide waverider with heat load constraint

Aircraft Engineering and Aerospace Technology: An International Journal 87/1 (2015) 67–78
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Abstract: Purpose – The purpose of the paper is to study the variation of optimal burnout angle at the end of the ascent phase and the optimal control deflection during the glide phase, that would maximize the downrange performance of a hypersonic boost-glide waverider, with variation in heat rate and integrated heat load limit. Design/methodology/approach – The approach used is to model the boost phase so as to optimize the burnout conditions. The nonlinear, multiphase, constraint optimal control problem is solved using an hp-adaptive pseudospectral method. Findings – The constraint heat load results for the waverider configuration reveal that the integrated heat load can be reduced by more than half with only 10 per cent penalty in the overall downrange of the hypersonic boost-glide vehicle, within a burnout speed range of 3.7 to 4.3

km/s. The angle-of-attack trim control requirements increase with stringent heat rate and integrated heat load bounds. The normal acceleration remains within limits.

Numerical Performance Study of Small Size Lifting-Body Reentry Vehicle

Applied Mechanics and Materials, 2013, Vol. 390, pp161-165

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Abstract: The multiphase numerical optimization study has been carried out for a 2-stage boost vehicle and small size X-33 type lifting-body reentry vehicle with heat rate and dynamic pressure constraint. The problem has been modeled as a nonlinear, multiphase optimal control problem with the objective to compute the optimum burn-out conditions as well as the best control deflections that would maximize the cross range performance of the boost-glide vehicle under study. The study has been performed using hp-adaptive Pseudospectral method. Comparative performance of the lifting-body vehicle with conventional ballistic missile trajectory has also been carried out. It has been found that for vehicle under study, and near maximum down range, the optimum burn-out angle is 13.6 degree which results in a cross-range of more than 100 km.

Aerodynamic optimization for hypersonic airfoil design based on local piston theory

Applied Sciences and Technology (IBCAST), 2016 13th International Bhurban Conference on

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Abstract: Aerodynamic optimization by numerical methods has always been of engineering interest with the great advancement of computers. This paper presents a highly efficient aerodynamic optimization method for hypersonic airfoil based on local piston theory. In the optimization procedure, local piston theory has been employed for unsteady pressure perturbations caused by geometrical modification from the baseline. Because unsteady pressure perturbations at hypersonic conditions could be calculated by local piston theory based on initial flow field results in the optimum searching process, only one steady-state solution is required. Therefore, the optimization method described in this paper is an extremely efficient technique which combines the advantages of steady CFD and the local piston theory and thus with zero-computational cost in optimum search process. In order to investigate the applicability of local piston theory on aerodynamic prediction for blunt leading edge shape, single-objective and multi-objective optimizations for NACA0008 at various Mach numbers have been conducted with the objective to improve the lift-to-drag ratio and moment coefficient, and the optimization results have been validated by CFD and it is concluded that the optimization method based on local piston theory could be used in a wide Mach range while keeping a satisfactory efficiency and accuracy, therefore it can be employed for hypersonic airfoil optimization in the process of initial design in the engineering application.

Bézier approximation based inverse dynamic guidance for entry glide trajectory

Control Conference (ASCC), 2013 9th Asian, 23-26 June 2013, Page(s): 1 - 6 ,Conference Location : Istanbul

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Abstract: An explicit entry guidance law has been developed using inverse dynamics approach. The inverse dynamics problem is solved through Bézier curve approximation of the vehicle trajectory. Most important and novel feature of the developed guidance law is its ability to satisfy the terminal angular and velocity constraints besides position constraints. Through shape preserving `Bézier parameters' the guidance law has the ability to control terminal velocity. For entry glide flight the guidance law incorporates limits on acceleration and attack angle which are converted from path constraints. The results demonstrate remarkably good efficiency in meeting terminal constraints.

Computational Aerodynamic Analysis of Plate /Jet - Interaction for Blunted Cone-Cylinder in Hypersonic Flows

5th WSEAS Int. Conf. on FLUID MECHANICS (FLUIDS'08) Acapulco, Mexico, January 25-27, 2008

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Abstract: - The present study was carried out as an extension of an earlier work [1] and [2] for a lateral jet/ plate interaction for conic geometries at incidence, now extended for a 10.4 degree cone-cylinder configuration for an incoming hypersonic flow at Mach 5.0, 6.0 and 9.7 at

different incidence angles. Aerodynamic effects were found analogous to lateral jet-interactions for different Mach numbers. Axial pressure distributions and static aerodynamic coefficients were determined using CFD tools; It has been concluded that short protuberance/ plate installed on a blunted cone-cylinder causes an increase in net normal force through altering pressure distribution, with a consequent development of a useful aerodynamic pitching moment, while similarity in predicted pressure distribution using CFD analysis with an overall prediction accuracy of ±10% was found with the experimental results.

Zahir, S., and Ye, Zhengyin; "Computational Aerodynamic Interaction of a Short Protuberance /Side Plate on a Blunted Cone Configuration in Hypersonic Flow"; AIAA-2006-3172; 24th Applied Aerodynamics Conference, CA, USA; 5-8 June 2006.

COMPUTATIONAL AERODYNAMIC BEHAVIOUR OF LOCATION AND INCLINATION OF LATERAL PLATE /JET - INTERACTIONS WITH HYPERSONIC FLOWFIELD

ICAS 2006, 25TH INTERNATIONAL CONGRESS OF THE AERONAUTICAL SCIENCES

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Abstract Hypersonic plate/ jet-interaction flow for blunted cone geometries is a topic of interest in the fields of aerodynamics and gas dynamics as its potential is being examined for its effectiveness to improve performance and efficiency of various aerodynamic configurations. In this sequence, objective of our previous work was to carry out a study of a lateral jet interaction with an incoming hypersonic flow at Mach 9.7 for a biconic configuration at incidences [1], later study was extended by modelling jet of cold air as a solid cylinder with sharp edges, projected as a plate analogous to jet [2], conic configuration considered for the study is an adaptation from reference [3]. Present study is now only focused to mounting of the cylindrical plates on a blunted cone at various locations and with different angular orientations, in this study aerodynamic flow behaviour is studied for a fixed location of plates placed aft and forward to a mean position, as well as with their different angular orientations, pitching forward and aft with the body centreline. Aerodynamic flow field behaviour was studied for hypersonic free stream interaction with lateral plate position and angles by visualizing axial and lateral pressure distributions and by plotting pressure contour plots. CFD calculations were made using PAK-3D [4], a Navier-Stokes solver.

Irfan A, Zhang Q, Tang Z M, et al. Electrochemical behavior and corrosion morphology of the SiCp/5A06 Al alloy composite. International Conference on Advanced Materials, Development and Performance. 2008.

Optimal trajectory and heat load analysis of different shape lifting reentry vehicles for medium range application

Defence Technology, 2015, pp1-12

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Abstract The objective of the paper is to compute the optimal burn-out conditions and control requirements that would result in maximum down-range/ cross-range performance of a waverider type hypersonic boost-glide (HBG) vehicle within the medium and intermediate ranges, and compare its performance with the performances of wing-body and lifting-body vehicles vis-a-vis the g-load and the integrated heat load experienced by vehicles for the medium-sized launch vehicle under study. Trajectory optimization studies were carried out by considering the heat rate and dynamic pressure constraints. The trajectory optimization problem is modeled as a nonlinear, multiphase, constraint optimal control problem and is solved using a hp-adaptive pseudospectral method. Detail modeling aspects of mass, aerodynamics and aerothermodynamics for the launch and glide vehicles have been discussed. It was found that the optimal burn-out angles for waverider and wing-body configurations are approximately 5 and 14.8, respectively, for maximum down-range performance under the constraint heat rate environment. The down-range and cross-range performance of HBG waverider configuration is nearly 1.3 and 2 times that of wing-body configuration respectively. The integrated heat load experienced by the HBG waverider was found to be approximately an order of magnitude higher than that of a lifting-body configuration and 5 times that of a wing-body configuration. The footprints and corresponding heat loads and control requirements for the three types of glide vehicles are discussed for the medium range launch vehicle under consideration.

Rizvi STI, Linshu H, Dajun X. Optimal trajectory analysis of hypersonic boost-glide waverider with heat constraint. Aircr Eng Aerosp Technol 2015;87(1):67e78. http://dx.doi.org/10.1108/AEAT-04-2013-0079.

Rizvi STI, Linshu H, Nasimullah. Vehicle performance tradeoff study of small size lifting re-entry vehicle. In: 10th international Bhurban conference on applied sciences & technology. Islamabad: National Centre for Physics, Quaid-i-Azam University; 2013. p. 154e62. http://dx.doi.org/10.1109/IBCAST.2013.6512149. IEEE.

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Numerical Simulation of Complex Hypersonic Flows

Journal of Space Technology, 2012, Vol. 1(1), pp1-6

1 IST Karachi, 2Beihang University Beijing, mrmukkarum@yahoo.com 1Dr. Mukkarum Husain, 2Dr. Chun Hian Lee Abstract— Shock/shock and shockwave/ boundary layer interactions are important features of hypersonic flow fields. These features commonly motivate a considerable region of separation followed by reattachment. The pressure loads produced by the shock/shock and shock wave/ boundary layer interactions and the high heating loads encountered at reattachment play a significant role in control surface effectiveness and structural integrity of the hypersonic vehicle. Consequently, CFD tools are under improvement for predicting the details of such complex flows, combined with validating experiments and verifying against basic theoretical relations. In present studies, complex hypersonic flow test cases, namely, compression corner, backward step, and double cone, containing shock/shock and shock wave/ boundary layer interactions are solved by using two different schemes, namely, TVD and low dissipative high resolution artificial compression methods (ACM). Comparison of numerical results against the available experimental data shows that the low dissipative, high resolution ACM provides better results than the TVD scheme. Separation vortex size calculated by low dissipative high resolution ACM method is larger than the size of the separation vortex calculated by the TVD scheme, depicts that the low dissipative high resolution ACM method induces less numerical dissipation and therefore more appropriate for complex shock/shock and shock wave/ boundary layer interactions flows.

Computer Aided Drafting,Design and Manufacturing》 2008年01期

GPS Navigation Using Adaptive Kalman Filter for Maneuvering Vehicle

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【摘要】： Several filter techniques were available for the GPS position estimation problem of maneuvering vehicle ranging from using different process noises to Interactive Multiple Model (IMM). The limitation of using standard Kalman filters is listed.The performance of proposed adaptive filter is compared with that of the standard ones,two types of dynamic modeling of the maneuvering vehicle are used.The simulation is based on the almanac data of the GPS satellites to compute its feasibility during the simulation time and position on shape 8 track with continuous vehicle maneuvering. The goal is to obtain computationally efficient filter with reasonable accuracy for vehicle in maneuvering situation. The filter proposed is an alternative to the filter proposed in Ref. [1] with low computational burden.

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Trajectory optimization study of a lifting body re-entry vehicle for medium to intermediate range applications

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Abstract

A numerical optimization study of lifting body re-entry vehicles is presented for nominal as well as shallow entry conditions for Medium and Intermediate Range applications. Due to the stringent requirement of a high degree of accuracy for conventional vehicles, lifting re-entry can be used to attain the impact at the desired terminal flight path angle and speed and thus can potentially improve accuracy of the re-entry vehicle. The re-entry of a medium range and intermediate range vehicles is characterized by very high negative flight path angle and low re-entry speed as compared to a maneuverable re-entry vehicle or a common aero vehicle intended for an intercontinental range. Highly negative flight path angles at the re-entry impose high dynamic pressure as well as heat loads on the vehicle. The trajectory studies are carried out to maximize the cross range of the re-entry vehicle while imposing a maximum dynamic pressure constraint of 350 KPa with a 3 MW/m^2 heat rate limit. The maximum normal acceleration and the total heat load experienced by the vehicle at the stagnation point during the maneuver have been computed for the vehicle for possible future conceptual design studies. It has been found that cross range capability of up to 35 km can be achieved with a lifting-body design within the heat rate and the dynamic pressure boundary at normal entry conditions. For shallow entry angle of −20 degree and intermediate ranges a cross range capability of up to 250 km can be attained for a lifting body design with less than 10 percent loss in overall range. The normal acceleration also remains within limits. The lifting-body results have also been compared with wing-body results at shallow entry condition. An hp-adaptive pseudo-spectral method has been used for constrained trajectory optimization.

Study on areothermoelastic for hypersonic all moving control surface

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Abstract: In this paper, the effect of the aerodynamic heating on shaft and the connection between the shaft and the body on areothermoelasticity for hypersonic all moving control surface is studied. A loosely coupled framework on aerothermoelastic stability boundary calculation for hypersonic vehicles is developed. Firstly, based on the computational fluid dynamics (CFD) technology, Navier-Stokes equation is solved to get the thermal environment. Then transient heat transfer of structure is analyzed. After that structural mode is analyzed under the effect of structure's thermal stress caused by temperature gradient and material property decrease caused by high temperature. Then structural mode is interpolated to the aerodynamic grids. Finally, Euler equation is solved to get flow parameters, and based on CFD local piston theory, aerothermoelasticity is analyzed in state space. The results show that: the heat transfer process and temperature distribution of the shaft structure are influenced obviously by the effect of the aerodynamic heating on shaft and the connection between the shaft and the body, and natural frequency and flutter characteristics are affected significantly, too. For the model in this paper, the effect of the aerodynamic heating on shaft and the connection between the shaft and the body on aeroelastic stability boundary is 8.31% and 6.87%, respectively.

Trajectory Optimization Study of a Lifting Body Re-entry Vehicle for Medium to Intermediate Range Applications

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Abstract: A numerical optimization study of lifting body re-entry vehicles is presented for nominal as well as shallow entry conditions for Medium and Intermediate Range applications. Due to the stringent requirement of a high degree of accuracy for conventional vehicles, lifting re-entry can be used to attain the impact at the desired terminal flight path angle and speed and thus can potentially improve accuracy of the re-entry vehicle. The re-entry of a medium range and intermediate range vehicles is characterized by very high negative flight path angle and low re-entry speed as compared to a maneuverable re-entry vehicle or a common aero vehicle intended for an intercontinental range. Highly negative flight path angles at the re-entry impose high dynamic pressure as well as heat loads on the vehicle. The trajectory studies are carried out to maximize the cross range of the re-entry vehicle while imposing a maximum dynamic pressure constraint of 350 KPa with a 3 MW/m2 heat rate limit. The maximum normal acceleration and the total heat load experienced by the vehicle at the stagnation point during the maneuver have been computed for the vehicle for possible future conceptual design studies. It has been found that cross range capability of up to 35 km can be achieved with a lifting-body design within the heat rate and the dynamic pressure boundary at normal entry conditions. For shallow entry angle of -20 degree and intermediate ranges a cross range capability of up to 250 km can be attained for a lifting body design with less than 10 percent loss in overall range. The normal acceleration also remains within limits. The lifting-body results have also been compared with wing-body results at shallow entry condition. An hp- adaptive pseudo-spectral method has been used for constrained trajectory optimization.

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Vehicle performance tradeoff study for a small size lifting re-entry vehicle

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Abstract: A wing-body re-entry vehicle has higher lift-to-drag ratio and enhances the down-range and the cross range of a ballistic vehicle. In the present study, trade-off analysis has been carried out between vehicle performance and flight parameters with variation in burn out angle at suborbital speeds. The vehicle during its re-entry flight is subjected to extreme heat rate and very high dynamic pressures. The re-entry range is maximized for shallow entry angles. Lowering the re-entry angle implies lowering the flight path angle at the burn out point. This results in increase in re-entry range and reduction of free flight range. These two parameters affect the overall range of the vehicle. Longer flight times at shallow re-entry angles also result in an increase of the total heat load. The burn-out angle also affects the g-load required to initiate the initial skip. This paper discusses the sensitivity of total heat load, maximum normal acceleration, range and the

flight time once the re-entry trajectory is optimized for maximum down range subject to maximum dynamic pressure constraint of 350 KPa and 3 MW/m^2 of heat rate limit for a range of burn-out velocities and burn-out angles. All trajectories within the matrix have been optimized for maximum down range/cross range using hp-adaptive pseudospectral method. The optimal angle-of-attack and bank angle control deflections have also been discussed. It has been found that for a boost-glide wing-body vehicle, the range advantage is of more than 35 percent as compared to bi-conic re-entry vehicle. Near optimal down range is obtained at burn-out angle of approximately 15 degree. The g-loads and angle-of-attack trim control requirements remain within limits. Cross-ranges of the order of 800 to 2000 km can be obtained with in the medium to intermediate range using wing-body re-entry vehicle design.

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