



## 第四届喷气推进与动力工程国际会议论文集

第四届喷气推进与动力工程国际会议科学委员会、组织委员会 主编

### ISJPPE 2012

# Proceedings of 4<sup>th</sup> International Symposium on Jet Propulsion and Power Engineering

Edited by

ISJPPE2012 Scientific Committee  
Organizing Committee

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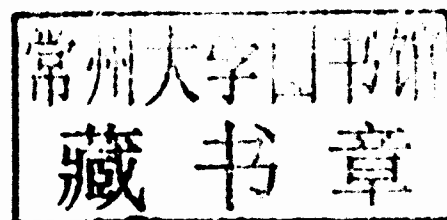
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# Preface

The 4th International Symposium on Jet Propulsion and Power Engineering (ISJPPE 2012) is going to be held on September 10 – 12, 2012, Xi'an China. As the co-organizers, NPU (Northwestern Polytechnical University of China), BUAA (Beihang University of China), NUAA (Nanjing University of Aeronautics and Astronautics of China) and RWTH (Aachen University of Germany) welcome the worldwide delegates to the ISJPPE 2012.

Started in 2006, ISJPPE is jointly organized by BUAA, RWTH, NPU and NUAA. As a biennial world event on jet propulsion and power engineering, ISJPPE provides a forum for engineers, researchers, and other professionals active in these fields to review the latest progress, exchange the latest results, and learn about the most advanced theories, technologies, and applications. A broad cooperation among expertise would like to provide a further impetus to consolidate recent advances in jet propulsion and power engineering.

The International Scientific Committee of ISJPPE 2012 consists of more than 30 experts in the related fields from both academia and industry. ISJPPE 2012 received more than 180 submissions from 12 different countries. After per reviewing, 113 papers have been accepted for publication in the conference proceedings and oral presentation. These papers cover a wide range of research interest related to the jet propulsion and power, including turbomachinery, internal flow, acoustics, heat and mass transfer, multiphase flows, reacting flows, combustion, advanced materials, structural strength, vibration and reliability, and engine design, control and health management.

In addition to a large number of technical paper submissions, we are blessed with 12 invited keynote presentations given by world-renowned scientists.

On behalf of the organizing committee, we would like to express our sincere appreciations to all viewers for their timely and outstanding efforts in reviewing the large number of papers. We are grateful to all authors, committee members, conference sponsors, and financial supporters. In addition, we would like to acknowledge the support of National Natural Science Foundation of China, Grant No. 51210305026.

We hope you have a unique, rewarding and enjoyable experience at ISJPPE 2012 in Xi'an, China.

ISJPPE 2012      Scientific Committee  
                         Organizing Committee  
                         July, 2012  
                         Xi'an, China

## Contents

### Session A: Turbomachinery, Internal Flow and Acoustics

#### Keynote

Thermodynamically Compatible Conservation Laws for Working Process Simulation in High Temperature Air Breathing Engines and for Simulation of Some Nature Processes

..... *M. Ja. Ivanov* (3)

#### Keynote

Automated Optimal Design of Subsonic and Supersonic Diffusers

..... *Doyle Knight* (13)

The Numerical Simulation of Sand Trajectory in Fan Air Flow Channel of Turbo-fan Engine

..... *ZEND Qiang, WU Tie-ying* (19)

Effects of Adverse Pressure Gradient on the Maximum Values of Reynolds Stresses in a

Turbulent Boundary Layer ..... *MA Wei, Ottavy Xavier, LU Li-peng, Leboeuf Francis* (24)

Prediction and Analysis of Distortion Inlet on Compressor Performance and Stability Using

Three Dimensional Model ..... ..

..... *SHI Pei-jie, QIAO Wei-yang, WEI Zuo-jun, CHEN Ping-ping* (28)

Numerical Investigations on the Leakage Flow and Rotordynamic Characteristics of Labyrinth Seal

..... *LI Zhi-gang, LI Jun, FENG Zhen-ping* (36)

Study of Small Flow Rate High Pressure Ratio Backswept Impeller Design .....

..... *GAO Li-min, XIE Jian, ZHU Qi-peng, MIAO Fang* (46)

A Model for Concentrated Vortices and an Unsteady Wake Model for Turbine .....

..... *WEI Zuo-jun, QIAO Wei-yang, ZHAO Lei, SHI Pei-jie* (51)

Study on Counter-Flow Thrust Vecotring Nozzle Jet Attachment and Control .....

..... *SHI Jing-wei, WANG Zhan-xue, ZHANG Xiao-bo, LIU Zeng-wen* (60)

Numerical Study of Cascade Self Noise ..... *WANG Liang-feng, QIAO Wei-Yang* (65)

The Influence of Axial Turbine Element Stage Stator/Rotor Axial Spacing on Flow Status

and Performance ..... *YANG Jie, QIAO Wei-yang* (70)

Experimental Investigation of Novel Casing Treatment with Bias Flow .....

..... *SUN Da-kun, LIU Xiao-hua, SUN Xiao-feng* (77)

Application and Optimization of Non-Axisymmetric End Wall in a High Pressure Turbine .....

..... *NA Zhen-zhe, LIU Bo* (86)

Minimizing Secondary Flow Losses in a High Pressure Turbine with Nonaxisymmetric Endwall

..... *CHEN De-sheng, LIU Bo* (94)

Theoretical and Numerical Investigation of the Hydrodynamic Stability of the Planar Taylor-Culick Flow

..... *LIU Pei-jin, YANG Shang-rong, WEI Xiang-geng, LIU Xin* (100)

Experimental Investigation of Axial Velocity Density Ratio in Large Camber Compressor Cascade .....	ZHANG Guo-chen, LIU Bo, SHI Lei, YANG Xiao-dong (106)
Optimization of Multi-Stage Axial Compressor Based on Stochastic Ranking Differential Evolution Algorithm .....	YANG Xiao-dong, LIU Bo, CAO Zhi-yuan, ZHANG Guo-chen (111)
PIV Investigation of Secondary Flows in a Low-Speed Axial Compressor Rotor Passage .....	CAO Zhi-yuan, LIU Bo (118)
Performance Improvement of a Degraded Heavy Duty Gas Turbine Using CFD Design Tools .....	Hamid Motamedi Zoka, Mohammadreza Shirzadi (124)
Research of Coaxial Gas Ejector .....	Haliulin R. R., Sychenkova E. V., Sychenkov V. A. (131)
Numerical Research of the Best Depth and Location of the Circumferential Groove of Subsonic Compressor .....	LIU Chuan-le, CHU Wu-li, ZHANG Hao-guang (134)
Numerical Simulation of Turbine Performance with Low Reynolds Number at High Altitude .....	YANG Lin, QIAO Wei-yang, LIU Jian, LUO Hua-ling, HOU Wei-tao (140)
Numerical Simulation of Three-Dimensional Separated Flow in a Linear Compressor Cascade .....	GAO Feng, MA Wei, Boudet Jérôme, Ottavy Xavier, LU Li-peng, Leboeuf Francis (149)
A Numerical Study of Active Flow Control for Low Pressure Turbine Blades .....	Christian Rohr, YANG Zhi-yin (157)
Influence of Turbulence Modeling on the Secondary Flow Prediction .....	WEI Zuo-jun, QIAO Wei-yang, SHI Pei-jie, ZHAO Lei (165)
2D Euler-Based Inverse Method: Development, Verification and Application .....	YANG Jin-guang, WU Hu (172)

## Session B: Heat and Mass Transfer

### Keynote

20 Years of Experiences for the Conjugate Heat Transfer Analysis of Convection-cooled Turbine Vanes

..... D. Bohn, K. Kusterer, G. Lin, N. Moritz (181)

### Keynote

Industrial Applications of Heat Transfer Enhancement: Review and Problem

..... Yu. F. Gortyshov, I. A. Popov (188)

### Keynote

Heat Transfer Augmentation Technologies for Internal Cooling of Turbine Components of Gas Turbine Engines

..... Phil Ligrani (199)

Thermodynamics Characteristic of the Flow and Heat Transfer in Rotating Cavity .....

..... WU Kang, REN Jing, JIANG Hong-de (232)



Experimental and Numerical Investigation of Impingement Cooling with Spent Flow in the Blade Leading Edge ..... YANG Li, REN Jing, JIANG Hong-de (240)

Numerical Simulations on the Flow Characteristics and Temperature Drop of an Aerodynamic Pre-swirl Hole ..... ZHANG Lin, LIU Gao-wen, JIANG Zhao-wu, LI Bi-yun (248)

Numerical Study of N-Decane Convective Heat Transfer with Endothermic Pyrolytic Reaction under a Constant Wall Temperature and Supercritical Pressures ..... RUAN Bo, WANG Lei-lei, WANG Jing-fan, MENG Hua (255)

Calculation of Plate Turbulent Shear Flow and Heat Transfer Using Extended GAO-YONG Model ..... WANG Yong, GAO Ge, LI Zhi-qiang (263)

Experimental Investigation on the Heat Transfer of Engine Similar Cooling Channel with Different Outflow Rate Allocation ..... LIANG Wei-ying, ZHU Hui-ren (268)

Investigation on the Thermal Behaviour of Aeroengine Bearing Chamber Using Thermal Networks ..... GAO Wen-jun, LIU Zhen-xia, LV Ya-guo (275)

Experimental and Numerical Investigation on the Film Cooling of Cylindrical Holes Embedded in a Trench ..... ZHANG Zong-wei, ZHU Hui-ren, WANG Meng-yuan, MENG Qing-kun (279)

Prediction of Turbulent Flow and Heat Transfer Within Rotating Ribbed Turning Passage ..... ZHAO Shu, ZHU Hui-ren, GUO Tao, ZHENG Jie, LIANG Wei-ying (285)

Turbulence Models Assessment on the Flow and Heat Transfer in a S-Bend Passage with Ribs ..... ZHENG Jie, ZHU Hui-ren, GUO Tao, ZHAO Shu, LIANG Wei-ying (293)

Heat Transfer Measurements for a Cooled Endwall in Short Duration Transonic Wind Tunnel ..... LI Hong-cai, ZHU Hui-ren, REN Zhan-peng, XU Du-chun (301)

Numerical Comparison of the Cooling Performance of a Shaped Hole Configuration and a Nekomimi Configuration ..... Karsten Kusterer, Nurettin Tekin, Dieter Bohn, Takao Sugimoto, Ryozi Tanaka, Masahide Kazari (308)

Application of Dynamic Mesh to Ice Accretion Simulation ..... LI Jing, LIU Zhen-xia, HU Jian-ping (317)

Effect of Rib Turbulators Angle-of-Attack on Heat Transfer and Pressure Drop in a U-duct Cooling Channel ..... Reza Torabideh, Hamid Motamedi Zokae, Reza Ghorbani (322)

Film Cooling Performance of Opponent Waist-shaped Slot Holes ..... LUO Jian-xia, ZHU Hui-ren (329)

## Session C: Multiphase Flows, Reacting Flows and Combustion

### Keynote

Innovations in Hypersonic Flow Simulation ..... J. S. Shang (339)

The Influence of the Inlet Resistance on the Pulse Detonation Turbine Engine ..... LI Xiao-feng, ZHENG Long-xi, QIU Hua, LU Jie (352)

Numerical Simulation of Aeroacoustic Phenomena in a Chamber with Backward-facing Step Flow ..... ZHANG Xiang-yu, HE Guo-qiang, LIU Pei-jin (357)

Modeling of Formation of Toxic Substances in the Laminar Diffusive Flame .....

- ..... *Valiev F. M. ,Schukin V. A. , Dunay O. V.* (365)  
 The Effects of Cavitation on Superheated Aviation Kerosene Atomization .....  
 ..... *FAN Zhen-cen, FAN Wei, ZHAO Lin* (370)  
 Experimental and Numerical Investigation on Backpressure in Valveless Air-breathing Pulse  
 Detonation Engine .....  
 ..... *PENG Chang-xin, WANG Zhi-wu, ZHENG Long-xi, CHEN Xing-gu, LU Jie* (376)  
 Numerical Simulation of Multi-Cycle Pulse Detonation Engine Working Process Initiated by  
 Small Energy ..... *WANG Wei, QIU Hua, FAN Wei, XIONG Cha* (382)  
 Numerical Study on Supersonic Combustion Using  $k-\omega$  SST Turbulence Model with  
 Compressibility Modifications ..... *NIU Dong-sheng, HOU Ling-yun* (387)  
 Tunable Diode Laser Absorption Spectroscopy (TDLAS) Technique for Velocity Measurements  
 of High-speed Combustion Gas ... *YANG Bin, HE Guo-qiang, LIU Pei-jin, QI Zong-man* (395)  
 CO<sub>2</sub> Emission Reductions and Economic Benefits from Vehicle EER (Exhaust Energy Recovery) .....  
 ..... *PENG Zhi-jun, LU Li-peng, YANG Xiao-yi* (399)  
 CFD Simulation for Combustion System Optimization of an HSDI Diesel Engine .....  
 ..... *PENG Zhi-jun, Raouf Mobasher* (405)  
 Parallel Computing of Jet Impingement During Ignition Transient Using Fluid-structure  
 Interaction ..... *Bilal Guerrache, HE Guo-qiang, LIU Pei-jin* (412)  
 Numerical Prediction of NO<sub>x</sub> Emission from a Model Civil Aircraft Engine Combustor .....  
 ..... *ZHANG Man, FU Zhen-bo, LIN Yu-zhen* (417)

## Session D: Advanced Materials, Structural Strength, Vibration and Reliability

- Crystalline Orientation Effect on Stress of Single Crystal Turbine Blade Considering Nonlinear  
 Contact Behaviour ..... *SUN Wan-chao, LU Shan* (427)  
 An Optimal Method of Disc Structure by ANSYS Parametric Design Language .....  
 ..... *ZHANG Sheng, ZHAO Ming, ZHANG Guo-qian* (433)  
 Experimental Research on the Dual-Rotor Dynamic Characteristics .....  
 ..... *DING Xiao-fei, LIAO Ming-fu, WANG Si-ji* (437)  
 Instability Caused by Cylindrical Surface Fit in Rotor System .....  
 ..... *ZENG Yao, LIAO Ming-fu, WANG Si-ji* (442)  
 The Experimental Research on the Vibration Performance of SFD in Maneuver Flight .....  
 ..... *LI Wei, LIAO Ming-fu, WANG Si-ji* (447)  
 Experimental Study of High Speed Dynamic Balance of Dual-rotor .....  
 ..... *QUAN Yong, LIAO Ming-fu, WANG Si-ji* (452)  
 Design and Experimental Investigation of Instability Turbo-pump Tester with Positioning  
 Sleeve Structure ..... *XU Shan-hong, LIAO Ming-fu, WANG Si-ji* (457)  
 Research on Vibration Fault of Certain Type Turbopump ..... *NING Xiao-long, LIAO Ming-fu* (462)  
 The Design of Counter-Rotating Dual-Rotor Experimental Apparatus .....  
 ..... *JIANG Yun-fan, LIAO Ming-fu, WANG Si-ji* (467)  
 A Whole Transfer Matrix Method for the Counter-Rotating Dual-Rotor System .....  
 ..... *JIN Lu, LIAO Ming-fu, WANG Si-ji* (473)  
 Experimental Investigation on Reducing Rotor Vibration by Elastic Support/Dry Friction

Damper in Maneuver Flight .....	SONG Ming-bo, LIAO Ming-fu, WANG Si-ji (478)
Theoretical and Experimental Study on the Relationship Between the Stiffness of the Squirrel Cage and the Damping Performance of the SFD .....	SANG Xiao-xiao, LIAO Ming-fu, WANG Si-ji (482)
Fuzzy Reliability Research on Vibration of Blades Considering Fuzziness of both Failure Zone and Influence Factors .....	ZHANG Meng, LU Shan (487)
Study on Erosion Behavior and Microscopic Structure of Multi-directional Braided Carbon-carbon Composites .....	WANG Lei, HE Guo-qiang, LI Jiang, PENG Li-na (492)
The Particle-reinforced Composite with Interfacial Debonding .....	GONG Jian-Liang, LIU Pei-Jin, LI Qiang (498)
State Judgment Based on Dynamic Stiffness for Aeroengine .....	LIU Zhan-chi, LIAO Ming-fu (502)

## Session E: Propulsion Engine Design, Control and Health Management

Overall Performance Calculation of Dual-mode Scramjet Engine .....	HUANG Xing, CHEN Yu-chun, LI Bo, LI Jie, CAI Yuan-hu (509)
Choice of Target Devices of Air-jet Engines .....	Panchenko V. I., GENG Jie-feng (514)
Modeling and Simulation of Intercooled Recuperated Aero-engine .....	GONG Hao, WANG Zhan-xue, LIU Zeng-wen, CAO Ming-dong (516)
Turboprop Engine Performance Simulation and Analysis .....	WANG Xiao-rong, WANG Zhan-xue, LIU Zeng-wen (521)
Research on Closed Loop Acceleration and Deceleration Control Philosophy of Turboshaft Engine .....	JIA Lin-yuan, CHEN Yu-chun, FAN Wei, YANG Long-long, HU Qiu-chen (525)
Investigation of Low Reynolds Number Effects on the Performance of Aeroengine .....	ZHOU Hong, WANG Zhan-xue, LIU Zeng-wen (532)
Method of Fuel Selection of Air-Turbo-Ramjet Based on CEA .....	LI Cheng, CAI Yuan-hu (536)
Analysis of Operating Parameters for Vertical TakeOff and Landing(VTOL) Aircraft Engine .....	LIU Shuai, WANG Zhan-xue, CAI Yuan-hu, LIU Zeng-wen (540)
A Study on Installed Performance of Aero Engine .....	ZHANG Xiao-bo, WANG Zhan-xue, SHI Jing-wei (543)
The Application of Bayesian in Health Intelligent Evaluation of Aerospace Propulsion System .....	YU Peng, WANG Yan-kai, LIAO Ming-fu (548)
LMI-based Unknown Input Observer Fault Diagnosis Approach for Aero-engine Compressor Discrete Model .....	HE Chen, ZHANG Xiao-dong, Ron J Patton (553)
An Optical Fiber Blade Tip Clearance Sensor for Propulsion Health Monitoring .....	JIA Bing-hui, ZHANG Xiao-dong (559)
Throttling Performance Analysis of Intercooled Recuperated Turbofan Aero-engine .....	SONG Xing-chao TANG Hai-long, CHEN Min (564)
Modeling and Design Analysis of a Temperature Amplifier for HMC based on AMESim .....	YAO Hua-ting, FU Xiao-lei, WANG Xi (570)
Numerical Simulation of Aircraft Power System Transient Performance .....	SHI Yang, TU Qiu-ye (576)
Performance of Multi-fuel Hybrid Engine for Blended Wing Body Aircraft .....	

- ..... *YIN Fei-jia , Arvind G. Rao* (581)
- Hierarchical Fuzzy Markov Modelling for System Safety of Power-plant .....
- ..... *Kulikov G. G. , Arkov V. Yu. , Abdulnagimov A. I.* (589)
- A New Method of Building Civil Turbofan Engine Model Used for Control and Fault  
Diagnosis .....
- ..... *ZHANG Shu-gang , GUO Ying-qing* (595)
- Research on Active Clearance Control System of HPT .....
- ..... *ZHANG Huan-rong , CAI Yuan-hu* (600)
- A Matlab/TrueTime Toolbox Based Simulator for Communication Network Research  
of Distributed Engine Control System .....
- ..... *XIE Zhen-wei , GUO Ying-qing* (606)
- Active Generalized Predictive Control of Aero-engine Turbine .....
- ..... *PENG Kai , FAN Ding , FU Qiang , LI Yong* (609)
- A Novel Approach Utilizing Improved Genetic Algorithm for Parameter Optimization of  
Compressor Guide Vane Regulator .....
- ..... *YANG Fan , FAN Ding , PENG Kai* (615)
- Design and Simulation of Aeroengine Three Stage Combination Vortex Pump .....
- ..... *FU Jiang-feng , LI Hua-cong* (620)
- New Experimental Capabilities of CIAM's Research Test Center .....
- ..... *E. V. Pavlyukov , S. B. Petrov , A. F. Shoulgin* (624)
- Numerical Analysis of Integrated Forebody/Propulsion System of Aircraft .....
- ..... *TIAN Jin-hu , QIAO Wei-yang , WEI Zuo-jun , SHANG Ren-chao , YANG Ying-kai* (630)
- Tip Clearance Measurement of H-shaped Rotor-Blade of Turbine .....
- ..... *XIONG Bing , CHEN Hong-min , HAN Wei , GUO Guang-hui* (638)
- A Global Convergent Genetic Algorithm and Its Application on Parameters Optimization  
of Nozzle Area Regulator .....
- ..... *PENG Kai , FAN Ding , YANG Fan , HU Xiao-lu* (643)

## Session F: Other Topics Related to Jet Propulsion and Power Engineering

- Analytical Simulation for Feed-oil Pump of Aero-engine .....
- ..... *REN Guo-zhe , LIU Zhen-xia , LV Ya-guo* (651)
- A New Controller Design Method for MIMO Time Delay Non-square Systems .....
- ..... *JIN Qi-bing , HAO Feng , ZHAO Liang , CHENG Zhi-jin* (656)
- Experimental Investigation on the Ejector Pump Effect in Jet Engine Test Facilities .....
- ..... *Stefan Bindl , Bastian Muth , Marcel Stöβel , Sebastian Brehm , Reinhard Niehuis* (663)
- A CFD Study of the Ejector Pump Effect within Jet Engine Test Facilities .....
- ..... *Bastian Muth , Stefan Bindl , Sebastian Brehm , Reinhard Niehuis* (673)
- High Bypass Turbofan Engine Exhaust Emission Prediction .....
- ..... *CAO Ming-dong , WANG Zhan-xue , CAI Yuan-hu , LIU Zeng-wen* (684)
- Numerical Simulation of Radar Scattering Characteristics of Spherical Convergent Flap  
Nozzle with Different Throat Shape .....
- ..... *GAO Xiang , YANG Qing-zhen , CHEN Li-hai , CUI Jin-hui* (688)
- Future Aircraft Cabins and Design Thinking: Optimisation vs. Win-win Scenarios .....
- ..... *Hall A. , Wuggetzer I. , Mayer T. , Childs P. R. N.* (693)
- Numerical Simulation of Combustion Organization in Ramjet of RBCC Engine .....
- ..... *PAN Ke-wei , HE Guo-qiang , QIN Fei , TANG Xiang* (702)
- Numerical Simulation on the Infrared Radiation Characteristics of 2-D Converged Nozzle

with Different Trailing Edge .....	<i>LI Yue-feng, YANG Qing-zhen, LI Xiang, HUAN Xia</i>	(708)
Numerical Simulation of RCS for Converged Nozzle with Different Outlet Shape .....	<i>LI Yue-feng, YANG Qing-zhen, GAO Xiang, WU Zheng-ke</i>	(714)
Numerical Study of Airfoil Flows with the $k-\sqrt{\omega}$ Model .....	<i>GAO Lin, JIANG Li-jun, CUI Shu-xin, GAO Ge</i>	(720)
Interaction of Repetitive Laser Pulse with Mach 8 Bow Shock .....	<i>YU Xiao-jing, YAN Hong</i>	(725)
Collaborative Simulation Technology of Matlab and Fluent Based on Shared File .....	<i>CHEN Xiao-lei, GUO Ying-qing</i>	(731)
Numerical Study on Control of Normal Shock-Boundary Layer Interaction in Supersonic Inlet .....	<i>CAI Fei-chao, CHEN Yu-chun</i>	(736)
Numerical Investigation on RBCC Engine Performance under Ramjet Mode by Using Strut Injection and Fuel-rich Burned Gas Piloting Combustion .....	<i>XU Chao-qi, HE Guo-qiang, LIU Pei-jin, QIN Fei</i>	(740)
Investigation on Positions of Fuel Injection of RBCC Engine in Scramjet Mode .....	<i>TANG Xiang, HE Guo-qiang, QIN Fei, LIU Pei-jin, PAN Ke-wei</i>	(747)
Failure Analysis and Microstrucral Changes of IN738LC Second Stage Gas Turbine Blades .....	<i>M. Torfeh, H. Farhangi</i>	(753)
A Modified Simulation Model for the Performance of Gas-Oil Separator .....	<i>HU Jian-ping, LIU Zhen-xia, LV Ya-guo</i>	(758)
CFD Study of Effusion Cooling .....	<i>Matthew Walton, YANG Zhi-yin</i>	(762)

**Session A**  
**Turbomachinery, Internal**  
**Flow and Acoustics**



# Thermodynamically Compatible Conservation Laws for Working Process Simulation in High Temperature Air Breathing Engines and for Simulation of Some Nature Processes

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## Abstract

The paper presents unified mathematical models of thermo-gas-dynamic process simulation for applied problems of air breathing engine creation and for theoretical analysis of some physics experimental data. In the first part of the paper we consider a coordination of thermodynamics and conservation laws by prediction of turbojet engine working process. This simulation is relevant to high class models based on real 3D geometry of turbojet engine flow path. They can be applied either in isolated unit components or in entire engine flow passage. The method of working process modeling considers all main features of engine working process (viscous and radiation losses, fuel application and combustion, air bleed and blow out, leakage from flow path, rotor and stator thermal dilatation, air humidity, rotor inertia and so on). The second part of the paper demonstrates simulation for explanation of new experimental data of modern physics. Here there are considered a few phenomenon and process which take place on a different scales (from atomic and nanotechnology scales up to astrophysical scales). We demonstrate simulations for astrophysics gamma-ray bursts, cosmic jets and dark matter.

## 1. Introduction

Thermogasdynamic calculations of high temperature jet and turbojet engines demands accurate simulation for detail description of whole working process, including heat addition and radiation losses in combustors and turbine. Well known experience of V generation engine creation has pointed out the imperfection of modern thermodynamic working process models (see, for example, [1-3]). The theoretically calculated in design stage engine parameters essentially differ from experimental data for first engine units. Hence, long and expensive development of new high temperature jet and gas turbine engines is required.

In the first part we consider simulation of complex working processes of jet engine different types. Here the paper present the gas dynamics model for the radiation components, the close systems of thermodynamic coordinated conservation laws and typical results for a turbojet engine simulation.

The second part of the paper demonstrates simulation for explanation of a few experimental results of modern physics and astrophysics. We demonstrate solutions for cosmic jet engines [4 – 6], gamma-ray bursts and a black hole model [7 – 9].

Achievements in experimental physics and nanotechnologies (see, for example, [10 – 12]) pointed out also that it would be useful additionally to study molecular and atomic structures. Registration of Cosmic

Microwave Background Radiation (CMBR) is among such achievements. The results of conducted researches indicated that frequency distribution of background radiation density corresponds to frequency distribution of radiation density from the black body with its temperature  $T=2.735$  K (near 3 K).

The second significant achievement is the discovery of Dark Matter (DM), which is also called “the hidden mass in the Universe”. Now we know that 96% whole matter in our Metagalaxy consists of DM. The baryonic substance accounts to only 4%. There were multiple attempts to describe the nature of DM, but none was successful yet (see, in particular, [13 – 15]).

The third important success is the discovery of vacuum polarization around electrons, protons and atomic centers. Intensive light impulse propagation leads to creation of electron-positron pair at the collision of two powerful electromagnetic pulses [16].

Possibility to determine the shape of separate atoms and molecules via scanning probe microscopy is the fourth important for us achievement of experimental physics. It became possible to see so called vander Waals spheres and real polarized space around atomic centers within van der Waals spheres.

Using emphasized achievements the more accurate simulation for nuclear, atomic and molecule structures have been considered in our paper. The equation for description of electrical potential distribution in polarized space is provided. We analyze the specific solution in polarized space of electron and proton with the presence



of some barriers, which allow electrons to be on corresponding orbits of atom in stationary states. That's why Thomson -Rutherford improved atomic model can be used, and we propose the method of STationary Electrons (STEL) for atomic and molecule structures description [17 - 19]. This model provides very forming via the linkage of stationary electrons on outer atomic orbits. Such spatial molecular structures are fully according to widely accepted physics and chemistry conception. We present also calculation results for nucleus internal structure of deuterium, tritium and helium  $^3\text{He}$  and  $^4\text{He}$ .

## 2. Internal aerodynamics of turbojet engine

United gas dynamic models, which takes place in flow paths of aircraft turbojet and turbofan engines, are presented. These models are relevant to high-class models based on real 3D geometry of engine flow path. They are also based on three-dimensional (3D), quasi-three-dimensional (two-dimensional (2D) with  $S_1$  and  $S_2$  planes) and one-dimensional (1D) approaches. The models can be applied either in isolated unit components or in entire engine flow passage. All approaches are closely connected among themselves. Together they form the dynamic system for efficiency analysis of entire engine flow path. This method of working process modeling considers all main features of engine working process (viscous losses, fuel addition and combustion, cooled air bleed and blow out, leakage from flow path, rotor and stator thermal dilatation, air humidity, rotor inertia and so on). Steady and transient modes of engine operation could be simulated via these models.

The unified mathematical model of the entire engine flow path is considered below (for detail, see [20 - 22]). The flow path includes air inlet, fan, bypass duct (if needed), compressor, main combustion chamber, high pressure and low pressure turbines, afterburner (if needed), and exhaust nozzle. The direct problem for specified flow path is being solved from the position of internal aerodynamics.

A turbojet bypass engine is sketchy shown on Fig. 1, where also there is emphasized multicomponent, multidimensional and multidiscipline of the considered problem.

The initial system of equations (Euler or Navier-Stokes) should be written in divergence form for the cylindrical coordinate system, which coincides with engine axis [20 - 22]. Rotor motion equations together with equations of chemical mixture state should be added to the initial system. Turbulence effects are described via two-parameter turbulence model [23].

For the convenience of numerical integration the initial system of equations can be written with the use of curvilinear coordinate system adapted to surfaces of flow path elements. The writing form of initial system of

equations remains divergent. Equations can be integrated via CFD method based on the Godunov's scheme [24 - 26].

In this study we use the Godunov method with next peculiarities for any case (1D, 2D and 3D): finite volume formulations; conservative in adaptive grids; implicit; up to 3d order of accuracy; exact solution for arbitrary discontinuity break down (for Riemann problem); high resolution of shock waves and other discontinuities; entropy condition (the 2D law of thermodynamics) is explicitly includes into the numerical procedures (no expansion shocks).

Unified 2D models play an important role in the analysis of engine aerodynamics. These models can be obtained from the initial system of equations via radial or circumferential coordinate averaging (Fig. 2). The 2D problem definition on  $S_1$  plane in variable thickness layer containing cascade can be obtained via radial coordinate averaging. The problem on  $S_2$  plane is obtained via circumferential averaging [27]. Here the Godunov method with to an arbitrary discontinuity break down is very convenient.

Equations of transient 1D flows can be obtained from 3D equations via radial and circumferential averaging (or via radial averaging of  $S_2$  plane equations). The method preserves a many features of  $S_2$  approach: exact solution near inlet and outlet edges, transonic effects, compatibility with shock waves and so on [20 - 22].

One-dimensional methods are extensively used for preliminary optimization of flow path parameters (stage distribution of heat drops, the selection of reactivity ratio) under input limits. The 1D method is also used for performance calculation of engine or its subassemblies.

Below we present a lot of practical applications for turbojet flow path designing with the use of considered approaches. The results of such calculations practically coincide with experimental data and parameters of already realized engine projects.

## 3. Thermogasdynamics model of radiation component

The zero law of thermodynamics allows introducing a temperature as the state parameter. The temperature  $T_0 = 2.735\text{K}$  characterizes of cosmic background microwave radiation state.

Application the first and second laws for radiation (photon gas) gives the connection between increasing of entropys, internal energy  $de$  and specific volume  $dv$  as

$$Td_s = de + pdv$$

Remembering that

$$de = \frac{\partial e}{\partial T}dT + \frac{\partial e}{\partial v}dv$$

this equation can be written