Preface

Since 2011, the International Workshop on Detonation for Propulsion (IWDP) has successfully brought together scientists worldwide for exchanging their accomplishments and new ideas in detonation applications for aerospace propulsion. This workshop seeks to highlight the latest developments in the research area of detonation and its applications. The workshop locations include Bourges (2011, Detonation Wave Propulsion Workshop), Busan (2011, 1st IWDP), Tsukuba (2012, 2nd IWDP), Tainan (2013, 3rd IWDP), Warsaw (2014, 4th IWDP), Beijing (2015, 5th IWDP), Singapore (2016, 6th IWDP), Poitier (2017, 7th IWDP), Xi'an (2018, 8th IWDP), and St. Petersburg (2019, 9th IWDP).

This booklet includes the extended abstracts of presentations delivered at the St. Petersburg's Workshop. The material is divided in three Chapters: Chapter 1 — Fundamentals; Chapter 2 — Liquid-Fuel Rotating Detonation Engines; and Chapter 3 — Applications.

Chapter 1 deals with the fundamentals of detonations with emphasis to the phenomena inherent in pulsed detonation engines (PDEs) and rotating detonation engines (RDEs).

Baranyshyn et al. analyze the dynamics of accelerating flames at deflagration-to-detonation transition (DDT) in a cylindrical tube applying high-speed video recording of flame self-luminescence and conventional local flow measurements in a stoichiometric acetylene–oxygen mixture diluted with argon or nitrogen.

Endo et al. report the results of their comparative experimental studies of DDT in ethylene–oxygen–nitrogen mixture under conditions of laser and spark-plug ignition and find the conditions for a significant reduction in the DDT run-up time and distance at laser ignition.

Semenov and Solomatin investigate numerically the mechanism of detonation propagation in the plane channel filled with nonuniform hydrogen–air mixture with transverse concentration gradient and emphasize the importance of the shock-induced motion of mixture pockets in the induction zone.

Davidenko and Gaillard present their three-dimensional (3D) LES-based numerical simulations of different injection elements for separate injection of gaseous hydrogen and oxygen in the RDE and claim the primary importance of injection pressure recovery and fresh mixture quality for the efficiency of the RDE.

Frolov et al. present the results of 3D numerical simulations of methane–oxygen RDE with separate supply of fuel components applying the coupled Finite-Volume – Joint Velocity – Scalar Probability Density Function approach and analyze the probability density functions of the fuel-to-oxygen equivalence ratio in the premixed gas pockets directly ahead of the rotating detonation front.

Gamba overviews the experimental observations of the RDE operation modes with diffrent inlet area and exit area restriction ratios and discusses various phenomena controlling the operation of the device, the dynamics of the detonation wave, and its ability to generate pressure gain.

Prakash and Raman investigate numerically the operation process in the methane–oxygen RDE with separate supply of fuel and oxidizer applying the UMdetFOAM, OpenFOAM, and Cantera-based compressible flow solver for the 3D Navier–Stokes equations coupled with the skeletal methane–oxygen kinetic mechanism.

Zitoun et al. present different experimental regimes of rotating detonation in hollow and annular combustors obtained in the new facility and estimate the effect of dilution of the fresh gas by burnt gases on detonation properties, velocity, and pressure in the RDEs.

Shan et al. present the results of two-dimensional (2D) numerical simulations of an unwrapped ethylene–air RDE with the injection of premixed fuel components using the detailed reaction mechanism of ethylene oxidation and analyze the effect of injection conditions on the RDE performance.

Fotia et al. present a new concept of the equivalent available pressure to compare the unsteady and nonuniform combustion devices like RDEs with traditional steady, constant-pressure devices in terms of their ability to create usable work or thrust.

Tsuboi presents the higher-order 3D numerical simulations of detonation with full chemistry models of ethylene and ammonia combustion and discusses the effects of the higher-order scheme on the fundamental detonation structure.

Matsuoka et al. present the results of 2D numerical calculations as well as the results of demonstration experiments of a novel continuous detonation device with repeating ethylene–oxygen detonation attenuation and reinitiation by shock reflection at the combustor side walls, so called reflective shuttling detonation device.

Yuanxiang Sun and Cheng Wang consider a simple model to study detonation behavior based on the analog differential equation which captures a rich set of detonation phenomena.

Chapter 2 deals with the research and development in the field of liquid-fuel RDEs and PDEs.

Po-Hsiung Chang et al. investigate the critical conditions for RDE operation with the direct injection of liquid Jet A1 in terms of the droplet size and local vaporized fuel/air ratio applying the laser diffraction system and the mid-infrared tunable diode laser absorption spectrometer technique for measuring fuel vapor concertation and droplet size distribution.

Bykovskii et al. investigate the continuous spin detonation (CSD) of the heterogeneous mixture of aviation kerosene TS-1 and air with and without addition of hydrogen in a 503-millimeter diameter annular/hollow combustor and register the CSD of the kerosene–air mixture in the hollow combustor at subcritical outflow of the combustion products and using kerosene bubbling with air.

Frolov et al. develop, fabricate, and test the kerosene-fueled continuous-detonation afterburner (CDA) for the commercially available small-size TJ100 turbojet engine and report the results of test fires with three modes of CDA operation: CSD, longitudinally pulsating detonation, and regular constant pressure combustion.

Wolański presents the overview of his long-term research on the application of RDEs to the kerosene-fueled gas turbine engine, rocket engine as well as rocket-ramjet combined-cycle jet engine.

Wei Fan et al. present their recent accomplishments of the detonation initiation characteristics of RP-3 kerosene thermal cracking products, the effect of obstacles in a liquid-fueled rocket PDE and detonation initiation in a supersonic flow.

Bing Wang and Qiaofeng Xie present the experimental and computational results on various aspects of gas-phase (H_2/air) and two-phase (kerosene droplets – oxygen-enriched air) RDEs: propagation of detonation waves and their stability.

Jeong-Yeol Choi presents the results of numerical simulation of multiinjector liquid rocket combustor, dual combustion ramjet and scramjet, as well as design and experimental studies on the liquid-fueled RDE for rocket propulsion and small-scale PDE for propulsion applications.

Yining Zhang et al. compare the results of 3D numerical simulations with long-duration (300 s) experimental firings of the liquid-fueled RDE in terms of the thermal loads on the combustor walls and obtain the agreement within 20% between the predicted and measured heat fluxes.

Chapter 3 deals with the various applications of the detonative combustion.

Kasahara et al. present the results of test fires of their methane–oxygen RDE designed for the technology-demonstration space flight onboard the sounding rocket S520-31 which will be launched by JAXA in August 2020.

Ivanov et al., using 3D numerical simulation of the axisymmetric hydrogen-fueled ramjet, explore the possibility of reducing the ramjet start-up Mach number by replacing deflagrative combustion with the continuous detonative combustion and obtain the lowest estimate on the level of Mach 1.3.

Paniagua et al. present their integrated computational and experimental campaign on coupling the RDE-combustor with the turbine and suggest a novel design of turbomachinery capable of withstanding a transonic and high-frequency pulsating flow with extreme pulsation amplitude.

Frolov et al. present the computational and experimental results on the performance of the valveless and valved pulsed detonation hydroramjets — novel propulsion devices for water vehicles developing thrust due to shock-induced pulsed water jets periodically emanating from the water guide nozzle.

Hao Meng et al. apply the multidimensional numerical simulation for designing the oblique detonation engine based on the premixed hydrogen–air approaching flow conditions.

We outlined the contents of the extended abstracts included in the booklet to enable easy selection of the subject of choice by the reader. A quick glance at the booklet contents indicates that there has been a considerable progress in the detonation research during last years.

Editors