

# **46th AIAA Fluid Dynamics Conference 2016**

Held at the AIAA Aviation Forum 2016

Washington, D.C., USA  
13 - 17 June 2016

Volume 1 of 5

ISBN: 978-1-5108-2741-7

**Printed from e-media with permission by:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571



**Some format issues inherent in the e-media version may also appear in this print version.**

The contents of this work are copyrighted and additional reproduction in whole or in part are expressly prohibited without the prior written permission of the Publisher or copyright holder. The resale of the entire proceeding as received from CURRAN is permitted.

For reprint permission, please contact AIAA's Business Manager, Technical Papers. Contact by phone at 703-264-7500; fax at 703-264-7551 or by mail at 34922 Uwptkug'Xcmg{ 'F tkxg."Uwkug"422, Reston, VA 20191, USA.

# TABLE OF CONTENTS

## VOLUME 1

### APA-06/FD-08: BIO-INSPIRED FLOWS

<b>Instantaneous Lift and Motion Characteristics of Butterflies in Free Flight (AIAA 2016-3252)</b> .....	1
<i>Madhu Sridhar, Chang-Kwon Kang, D Brian Landrum</i>	
<b>Three-Dimensional Numerical Simulation of Hummingbird Forward Flight (AIAA 2016-3253)</b> .....	21
<i>Jialei Song, Haixiang Luo, Bret Tobalske, Tyson Hedrick</i>	
<b>Influence of Vortical Interactions on Thunniform Fish Motions (AIAA 2016-3254)</b> .....	34
<i>Kislaya Srivastava, Karthikeyan Duraisamy</i>	
<b>Bio-Inspired Sinusoidal Leading-Edged Wings (AIAA 2016-3255)</b> .....	52
<i>Martiqua Post, Anthony R. Sapell, Jonathan S. Hart</i>	

### APA-41/FD-63: LOW SPEED, LOW REYNOLDS NUMBER AERODYNAMICS

<b>Evolution of the Non-linear and Unsteady Low Reynolds Number Laminar Separation Bubble around the Airfoil with Small Angle of Attack (AIAA 2016-4337)</b> .....	68
<i>Bai Peng, Feng Li, Qiang Liu, Huiling Zhan</i>	
<b>Toward Simulating a Pitch-Up Maneuver for a Small Unmanned Aerial Vehicle (AIAA 2016-4338)</b> .....	82
<i>Joshua D. Blake, David S. Thompson</i>	
<b>Quantification and Analysis of Propulsive Wake Topologies in Finite Aspect-Ratio Pitching-Rolling Plates (AIAA 2016-4339)</b> .....	110
<i>Chengyu Li, Haibo Dong</i>	
<b>Modeling of Pitching and Plunging Airfoils in Proximity for Thrust Generation (AIAA 2016-4340)</b> .....	124
<i>Alexander Povitsky</i>	
<b>Experimental Investigation of Aspect-Ratio-One Wing Characteristics at Low Reynolds Numbers (AIAA 2016-4341)</b> .....	134
<i>Makoto Mizoguchi, Hajime Itoh</i>	
<b>An Experimental and Numerical Study of Laminar Separation on Elliptic Airfoil at Low Reynolds Numbers (AIAA 2016-4342)</b> .....	147
<i>Liu Yang, Xuanshi Meng, Xu Yan, Feng Liu, Shijun Luo</i>	

### APA-42/FD-64: VORTEX/VORTICAL FLOWS II

<b>Further Investigations of the Tip Vortex on an Oscillating NACA0012 Wing (AIAA 2016-4343)</b> .....	159
<i>Daniel J. Garmann, Miguel Visbal</i>	
<b>Effect of Upsweep Angle on Afterbody Vortices (AIAA 2016-4344)</b> .....	181
<i>Dinita Bulathsinghala, Zhipin Wang, Ismet Gursul</i>	
<b>Vortical Flow Structure Genesis of Lobed Nozzle Flows (AIAA 2016-4345)</b> .....	206
<i>Markus Ruetten, Fithawi Woldegorgis</i>	
<b>Dynamical System Analysis on the Onset of Recirculating Flow Region Associated with Vortex Breakdown (AIAA 2016-4347)</b> .....	225
<i>Kento Yamada, Kojiro Suzuki</i>	
<b>Flow Past Rotating Low Axis Ratio Elliptic Cylinder (AIAA 2016-4348)</b> .....	238
<i>Sandeep N. Naik, S. Vengadesan, K. Arul</i>	

### FD-02: GEOMETRY AND MESHING

<b>High-Order Mesh Curving Using WCN Mesh Optimization (AIAA 2016-3178)</b> .....	248
<i>Steve L. Karman, J T. Erwin, Ryan S. Glasby, Douglas Stefanski</i>	
<b>Curved Mesh Generation Using Radial Basis Functions (AIAA 2016-3179)</b> .....	283
<i>Aditya Kashi, Hong Luo</i>	
<b>An Adaptive Remeshing Strategy for Unsteady Aerodynamics Applications (AIAA 2016-3180)</b> .....	294
<i>Alexandre Limare, Pierre Brenner, Houman Borouchaki</i>	
<b>Telescopic Approach for Extreme-Scale Parallel Mesh Generation for CFD Applications (AIAA 2016-3181)</b> .....	308
<i>Nikos P. Chrisochoides</i>	
<b>Singular Mesh Generation from Multiple Overset Meshes: a Tool for Industrial Applications (AIAA 2016-3182)</b> .....	316
<i>Gennaro Abbruzzese, Marta Cordero Gracia, Mariola Gómez López</i>	
<b>Comparison of Linear and Non-linear Elasticity Large Displacement Mesh Deformation in Computational Fluid Dynamics (AIAA 2016-3183)</b> .....	328
<i>Behrouz Shamsaei, James C. Newman</i>	





















<b>Flow Simulations of The Dynamics of a Perturbed Solid-Body Rotation Flow (AIAA 2016-4388).....</b>	4129
<i>Chunjuan Feng, Feng Liu, Zvi Rusak, Shixiao Wang</i>	

#### **FD-67: COMPUTATIONAL MODELING FOR PROPULSION APPLICATIONS**

<b>Advanced Modelling of Turbulent Heat-Flux in Turbofan Engines with Lobed Mixers (AIAA 2016-4389).....</b>	4152
<i>Jens Trümmer, Christian Mundt</i>	
<b>Numerical Investigation of Asymmetric Lobe Structure on Aerodynamic Performance of a Lobed S-Shaped Nozzle (AIAA 2016-4390).....</b>	4167
<i>Liwei Du, Youhong Liu, Yulin Ding, Haoliang Ren</i>	
<b>Scramjet Combustor Flow Analysis Using Coupled Navier-Stokes and Finite Rate Chemical Equations (AIAA 2016-4391).....</b>	4198
<i>Ramin Rouzbar, Sinan Eyi</i>	
<b>Numerical Simulations of Gas-Centered Swirl-Coaxial Injectors for Rocket Engine Applications. Evaluating the Ability of "Standard" Turbulence Models in Capturing the Complex Nature of Spray Atomization (AIAA 2016-4392).....</b>	4215
<i>Larry A. Villasmil</i>	
<b>Evaluation of CFD Codes for Swirl-Driven Combustors (AIAA 2016-4393).....</b>	4229
<i>Gerardo Talamantes, Brian A. Maicke</i>	

#### **FD-68: THEORETICAL/FUNDAMENTAL FLUID DYNAMICS**

<b>Advanced Kinetic Theory for Polyatomic Gases at Equilibrium (AIAA 2016-4394).....</b>	4240
<i>James M. Chen</i>	
<b>Spatio-Temporal Response of a Laminar Separation Bubble Under Impulsive Forcing (AIAA 2016-4395).....</b>	4247
<i>Theodoros Michelis, Marios Kotsonis</i>	
<b>Phase Relationships Between Velocity, Wall Pressure, and Wall Shear Stress in a Forced Turbulent Boundary Layer (AIAA 2016-4396).....</b>	4261
<i>Kevin T. Rosenberg, Subrahmanyam Duvvuri, Mitul Luhar, Beverley J. McKeon, Casey Barnard, Brett Freidkes, Jessica Meloy, Mark Sheplak</i>	

#### **FD-69: UNCERTAINTY QUANTIFICATION AND SENSITIVITY ANALYSIS**

<b>A Multi Level Monte Carlo Algorithm for the Treatment of Geometrical and Operational Uncertainties in Internal and External Aerodynamics (AIAA 2016-4398).....</b>	4268
<i>Michele Pisaroni, Penelope Leyland, Fabio Nobile</i>	
<b>Sensitivity Analysis on Chaotic Dynamical System by Non-intrusive Least Square Shadowing (NI-LSS) (AIAA 2016-4399).....</b>	4286
<i>Angxiao Ni, Patrick J. Blonigan, Mario Chater, Qiqi Wang, Zhichao Zhang</i>	
<b>The Effect of Grid Topology and Flow Solver on Turbulence Model Closure Coefficient Uncertainties for a Transonic Airfoil (AIAA 2016-4400).....</b>	4302
<i>John A. Schaefer, Serhat Hosder, Mortaza Mani, Andrew W. Cary, Joshua Krakos</i>	
<b>Uncertainty Quantification of Turbulence Model Coefficients in OpenFOAM and Fluent for Mildly Separated Flows (AIAA 2016-4401).....</b>	4342
<i>Kimon Stephanopoulos, Isaac Witte, Tim Wray, Ramesh K. Agarwal</i>	
<b>Author Index</b>	