

# **Aeromechanics for Advanced Vertical Flight Technical Meeting 2020**

Held at Transformative Vertical Flight 2020

San Jose, California, USA  
21-23 January 2020

ISBN: 978-1-7138-0633-2

**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.  
These proceedings were created from a scanned original document, and are the best quality available.**

Copyright© (2020) by Vertical Flight Society  
All rights reserved.

Printed with permission by Curran Associates, Inc. (2020)

For permission requests, please contact Vertical Flight Society  
at the address below.

Vertical Flight Society  
2701 Prosperity Ave, Suite 210  
Fairfax, VA 22031  
USA

Phone: (703) 684-6777  
Fax: (703) 739-9279

[www.vtol.org](http://www.vtol.org)

**Additional copies of this publication are available from:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571 USA  
Phone: 845-758-0400  
Fax: 845-758-2633  
Email: [curran@proceedings.com](mailto:curran@proceedings.com)  
Web: [www.proceedings.com](http://www.proceedings.com)

## TABLE OF CONTENTS

### ACOUSTICS 1

Parametric Aeroacoustic Analysis of Two Fans in Hover Flight Condition .....	1
<i>Bernardo Pacini, Giovanni Droandi, Monica Syal</i>	
Development of Instrumentation and Methods for Time-Domain Measurement of Rotor-Type	
Noise Sources in a Hard Wall Wind Tunnel .....	10
<i>Nathan J. Burnside, William C. Horne</i>	
Acoustic Testing of the Bell 699 Rotor in the National Full-Scale Aerodynamics Complex 40- by	
80- Foot Wind Tunnel in Conversion and Airplane Configuration	
Schatzman, NASA Ames	
Research Center.....	21
<i>Kelly Sheltis, Natasha</i>	
A Quiet Helicopter for Air Taxi Operations.....	36
<i>Wayne Johnson</i>	

### ACOUSTICS 2

Aeroacoustic Predictions of the Free-Wake, Vortex Particle Method, and Computational Fluid	
Dynamics for a Coaxial Rotor System .....	48
<i>Kalki Sharma, Kenneth S. Brentner, Zhongqi Jia, Seongkyu Lee</i>	
Predictive Acoustic Modeling of Open Propellers Using Analytical Tools and RANS Simulations .....	66
<i>Dominic Lallier-Daniels, F. Bolduc-Teasdale, S. Moreau, M. Lpvesque-Leduc, D. Rancourt,</i>	
<i>P. Guilleminot-Simon, M. Sanjose</i>	
Investigation of Propeller-Wing Interaction Noise and the Potential Contribution to eVTOL Noise .....	78
<i>Bhaskar Mukherjee, Kenneth S. Brentner</i>	

### AERODYNAMICS AND FLIGHT DYNAMICS

Computational Studies to Understand Flight Stability and Control of a Robotic Hummingbird .....	93
<i>Xuan Yang, Moble Benedict</i>	
Rapid Vehicle Aerodynamic Modeling for Stability and Control Analysis .....	104
<i>Javier E. Pascasio, Amanda Grubb, Marilyn J. Smith</i>	
An Integrated Simulation Tool for e-VTOL Aeromechanics and Flight Control Analysis .....	115
<i>Jean-Pierre Theron, Joseph F. Horn, Daniel A. Wachspress</i>	

### AERODYNAMICS 1

Recent Efforts Enabling Future Mars Rotorcraft Missions .....	131
<i>Shannah Withrow-Maser, Witold Koning, Winnie Kuang, Wayne Johnson</i>	
The Influence of Laminar-Turbulent Transition on Rotor Performance at Low Reynolds Numbers.....	141
<i>Finbar Argus, Geoffrey Ament, Witold Koning</i>	

An Experimental Investigation on the Dynamic Ice Accretion Process and Its Effects on the Aeromechanic Performance of Drone Propellers .....	151
<i>Zhe Ning, Nianhong Han, Yang Liu, Hui Hu</i>	

## **AERODYNAMICS 2**

Impact of Configuration Changes on the Wake Breakdown of Hovering Rotors .....	171
<i>Jennifer N. Abras, Nathan Hariharan</i>	
Aerodynamic Analysis of an Asymmetric Lift-Offset Compound Helicopter in Forward Flight using the Mercury CFD Framework.....	183
<i>Jan-Arun Faust, Yong Su Jung, James Baeder, Jürgen Rauleder</i>	
Vertical Climb Testing of a Full-Scale Proprotor on the Tiltrotor Test Rig.....	199
<i>C.W. Acree Jr.</i>	

## **AEROELASTICITY**

Aeroelastic Simulation of the UH-60M Fuselage.....	214
<i>Nicolas D. Reveles, Tyler J. Pierce, Eric L. Blades, Sandeep Agarwal, Byung-Young Min, Bill A. Welsh</i>	
Aeroelastic Stability Analysis of Hingeless Coaxial Rotors in Hover and Forward Flight .....	224
<i>Puneet Singh, Peretz P. Friedmann</i>	
Vortex Particle Method Whirl-Flutter Predictions of a Tiltrotor with Wing Extensions .....	244
<i>Ethan Corle, Matthew Floros, Sven Schmitz</i>	

## **CFD METHODS**

Improvements to Automated Strand Meshing Capabilities for Rotary Wing Applications Geometric Algorithms.....	259
<i>Vinod Lakshminarayan, Andrew Wissink, Rohit Jain, Jayanarayanan Sitaraman</i>	
Multirotor Trim using Loose Aerodynamic Coupling .....	276
<i>Austin D. Thai, Beatrice Roget, Jay Sitaraman, Sheryl M. Grace</i>	
Assessment of Different CFD Download Strategies with Helios .....	295
<i>Andrew Wissink, Vinod Lakshminarayan, Dylan Jude, Buvana Jayaraman, Jayanarayanan Sitaraman</i>	

## **CYCLOIDAL ROTORS AND TEST BED DESIGN**

Understanding Upward Scalability of Cycloidal Rotors for Large-Scale UAS Applications .....	311
<i>Atanu Halder, Moble Benedict</i>	
Mechanical Design of the Multirotor Test Bed .....	331
<i>Sarah Conley, Carl Russell</i>	
Prototype of Cycloidal Rotor with Elliptical Trajectory of Blade .....	345
<i>Alexander Balitsky, Mykola Maliar</i>	

## **DYNAMIC INFLOW**

Calibration of Velocity Potential Superposition Inflow Model using Computational Fluid Dynamics Data .....	353
<i>Po-Wei Chen, Feyyaz Guner, Lakshmi N. Sankar, J.V.R. Prasad, Chengjian He</i>	
Experiments and Computations Towards an Improved Understanding and Modeling of the Dynamic Inflow of Rotors in Hover .....	362
<i>Stefan Platzer, Jürgen Rauleder, Manfred Hajek, Patrick Mortimer, Palash Jain, Jayant Sirohi</i>	
An Approximate Finite State Dynamic Wake Model for Predictions of Inflow Below the Rotor .....	379
<i>Feyyaz Guner, J.V.R. Prasad, David A. Peters</i>	

Coupled Inflow and Structural Dynamics of a Coaxial Rotor with Time Delays and Adjoint Variables Including Multiple Inflow States .....	390
<i>Cory Seidel, David Peters</i>	

## **INTERACTIONAL AERODYNAMICS 1**

Simulation of Airfoil Interaction in Co-Rotating Coaxial Rotors with Uncertainty Quantification .....	402
<i>Miranda Costenoble, James Baeder, Rajneesh Singh, Phuriwat Anusonti-Inthra</i>	
Modeling and Analysis of eVTOL Air Vehicle Interactional Aerodynamics and Mission Performance .....	413
<i>Jeewoong Kim, Chengjian He, Jan Goericke</i>	
Impact of Vortex–Wake Interference on Rotor Trim .....	427
<i>Berend G. van der Wall</i>	

## **INTERACTIONAL AERODYNAMICS 2**

Analysis of the Interactional Aerodynamics of the Vahana eVTOL Using a Medium Fidelity Open Source Tool .....	436
<i>Davide Montagnani, Matteo Tugnoli, Alex Zanotti, Monica Syal, Giovanni Droandi</i>	
Prediction of the Aerodynamic and Acoustic Impact of Propeller-Wing Interference .....	452
<i>Jianhua Zhang, Kenneth S. Brentner, Edward C. Smith</i>	
An Experimental Study on the Rotor-to-Rotor Interactions of Small Unmanned-Aerial-Vehicle Propellers .....	464
<i>Wenwu Zhou, Zhe Ning, Hui Hu</i>	

## **PERFORMANCE**

Investigation into Dynamic Calibration and Rotor-Body Interaction .....	479
<i>Robert P. Thornburgh, Matthew L. Wilbur, Andrew R. Kreshock, Brendon D. Malovrh</i>	
Investigation of Stacked Rotor Performance in Hover Part 1: Experimental Measurements .....	490
<i>Chloe Johnson, Jayant Sirohi, George Jacobellis, Rajneesh Singh, Rob McDonald</i>	
Investigation of Stacked Rotor Performance in Hover Part 2: Computational Validation .....	501
<i>George Jacobellis, Rajneesh Singh, Chloe Johnson, Jayant Sirohi, Rob McDonald</i>	

Forward Flight Rotor Performance at Martian Atmospheric Densities and Sensitivity to Low Reynolds Numbers .....	513
<i>Brenda Natalia Perez Perez</i>	

## **ROTOR LOADS**

Loads Correlation of a Full-Scale Proprotor on the Tiltrotor Test Rig .....	529
<i>Sesi Kottapalli</i>	
Machine Learning Based Aerodynamic Models For Rotor Blades .....	562
<i>Daniel Martinez, Jay Sitaraman, Wesley Brewer, Peter Rivera, Dylan Jude</i>	
Predicting Wake and Structural Loads in RPM Controlled Multirotor Aircraft .....	575
<i>Abhishek Shastry, Anubhav Datta</i>	

## **VIBRATION**

Influence of Atmospheric Turbulence on Helicopter Elastic Rotor Hub Vibrations .....	590
<i>Willem Rex, Manfred Hajek</i>	
Quadcopter Rotor Phasing for Minimization of Aircraft Vibratory Loads .....	608
<i>Nicholas Kopyt, Robert Niemiec, Farhan Gandhi</i>	
Vibration Reduction Simulations for Rotor and Airframe of a Lift-offset Compound Helicopter Using Two Active Vibration Control Techniques .....	620
<i>Ye-Lin Lee, Do-Hyung Kim, Jae-Sang Park, Sung-Boo Hong</i>	

## **Author Index**