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High-Fidelity Numerical Ice Prediction on Rotors

Myles Morelli * and Alberto Guardone†

Department of Aerospace Science and Technology, Politecnico di Milano

Building B12, Via La Masa 34, Milano, MI 20156, Italy

Abstract: *In-flight icing encounters can jeopardise the performance and handling qualities of rotorcraft and hence pose a serious threat to flight safety.[1] As a consequence, numerical techniques have received interest as an alternative approach towards understanding the rotorcraft icing phenomena. Hybrid two/three-dimensional reduced-order methods have predominantly been used for the prediction of rotorcraft ice accretion over the past decade,[2–9] which is disconcerting given that rotorcraft are dominated by three-dimensional flow features. Recently work published at Nanjing University of Aeronautics and Astronautics provided the first fully three-dimensional rotor icing technique.[10–12]*

This work seeks to further establish high-fidelity, three-dimensional rotorcraft icing prediction codes in an effort to improve rotorcraft safety in the harshest of cold weather environments. A critical area which requires attention is the operation of rotorcraft in Supercooled Large Water droplets (SLD). Attempting to replicate such icing conditions using standard artificial in-flight icing trails and sub-scale experimental models has been identified to be particularly challenging. Furthermore, clouds containing SLD are associated with high rates of ice accretion and subsequently represent some of the most dangerous conditions.

Within this work a new framework is introduced to simulated rotorcraft icing in SLD conditions. The framework presents techniques including radial basis function mesh deformation, Lagrangian particle tracking, and ice shedding to simulate rotorcraft icing. The experiment conducted on the Spinning Rotor Blade (SRB-II) sub-scale model rotor has been chosen for the assessment of the numerical models in regular icing conditions. Numerical predictions of the ice accretion and shedding process are presented for several temperature-dependent tests. Quantities used for comparisons between the numerical predictions and experimental measurements on the SRB-II include the ice thickness and shedding location. Numerical predictions are shown to be in good agreement with the measured data at all temperatures. Additionally, the outcome of influential parameters which directly impact rotor ice shapes are assessed. In particular, the model for the temperature profiles within the ice layer, and the centrifugally induced movement of the liquid film. Hereinafter, the operation of the SRB-II rotor in SLD conditions is investigated. To that end, the influence of droplet splashing on impact is highlighted as being of first order importance for SLD. The location of the primary and secondary droplets is presented and its influence of the ice accretion.

*PhD Candidate, mylescarlo.morelli@polimi.it
†Professor, alberto.guardone@polimi.it

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References

[1]Gent, R., Dart, N., and Cansdale, J., "Aircraft Icing," *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences*, Vol. 358, No. 1776, 2000, pp. 2873–2911, https://doi.org/10.1098/rsta.2000.0689.

[2]Bain, J., Sankar, L., Egolf, T., Flemming, R., and Kreeger, R., "Progress Towards Modeling the Effects of Ice Accretion on Rotorcraft Performance in Hover and Forward Flight," *35th European Rotorcraft Forum*, Hamburg, Germany, September 2009.

[3]Rajmohan, N., Bain, J., Nucci, M., Sankar, L., Flemming, R., Egolf, T. A., and Kreeger, R., "Icing Studies for the UH-60A Rotor in Forward Flight," *American Helicopter Socitety Aeromechanics Specialists Conference*, San Francisco, California, USA, January 2010.

[4]Nucci, M., Bain, J., Sankar, L., Egolf, T. A., Flemming, R., and Kreeger, E., "A Methodology for Modeling the Effects of Icing on Rotary Wing Aerodynamics," *48th AIAA Aerospace Sciences Meeting*, Orlando, Florida, USA, January 2010.

[5]Bain, J., Deresz, R., Sankar, L., Egolf, T. A., Flemming, R., and Kreeger, E., "Effects of Icing on Rotary Wing Loads and Surface Heat Transfer," *49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition*, Orlando, Florida, USA, January 2011, p. 1100.

[6]Narducci, R. and Kreeger, R. E., "Analysis of a Hovering Rotor in Icing Conditions," *American Helicopter Society 66th Annual Forum*, Phoenix, Arizona, USA, 2010.

[7]Narducci, R., Orr, S., and Kreeger, R. E., "Application of a High-Fidelity Icing Analysis Method to a Model-Scale Rotor in Forward Flight," *American Helicopter Society 67th Annual Forum*, Virginia Beach, Virginia, USA, May 2011.

[8]Kelly, D., Fouladi, H., Fossati, M., Habashi, W. G., Alicino, R., Quaranta, G., and Masarati, P., "Assessment of Ice Accretion Effects on Rotor Dynamics via Multi-Body and CFD Approaches," *70th American Helicopter Society International Annual Forum 2014*, American Helicopter Society, 2014, pp. 1840–1851.

[9]Kelly, D., Habashi, W. G., Quaranta, G., Masarati, P., and Fossati, M., "Ice Accretion Effects on Helicopter Rotor Performance, via Multibody and CFD Approaches," *Journal of Aircraft*, Vol. 55, No. 3, 2018, pp. 1165–1176.

[10]Zhao, G.-q., Zhao, Q.-j., and Chen, X., "New 3-D Ice Accretion Method of Hovering Rotor Including Effects of Centrifugal Force," *Aerospace Science and Technology*, Vol. 48, 2016, pp. 122–130.

[11]Xi, C. and Qi-Jun, Z., "Numerical Simulations for Ice Accretion on Rotors Using New Three-Dimensional Icing Model," *Journal of Aircraft*, Vol. 54, No. 4, 2017, pp. 1428–1442.

[12]Chen, X., Zhao, Q., and Barakos, G., "Numerical Analysis of Aerodynamic Characteristics of Iced Rotor in Forward Flight," *AIAA Journal*, Vol. 57, No. 4, 2019, pp. 1523–1537.

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