Atmospheric Ice Accretion on Wind Turbine Blades: Numerical Modeling and Anti/De-Icing System

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Samsung Heavy Industries

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Overview of GNU

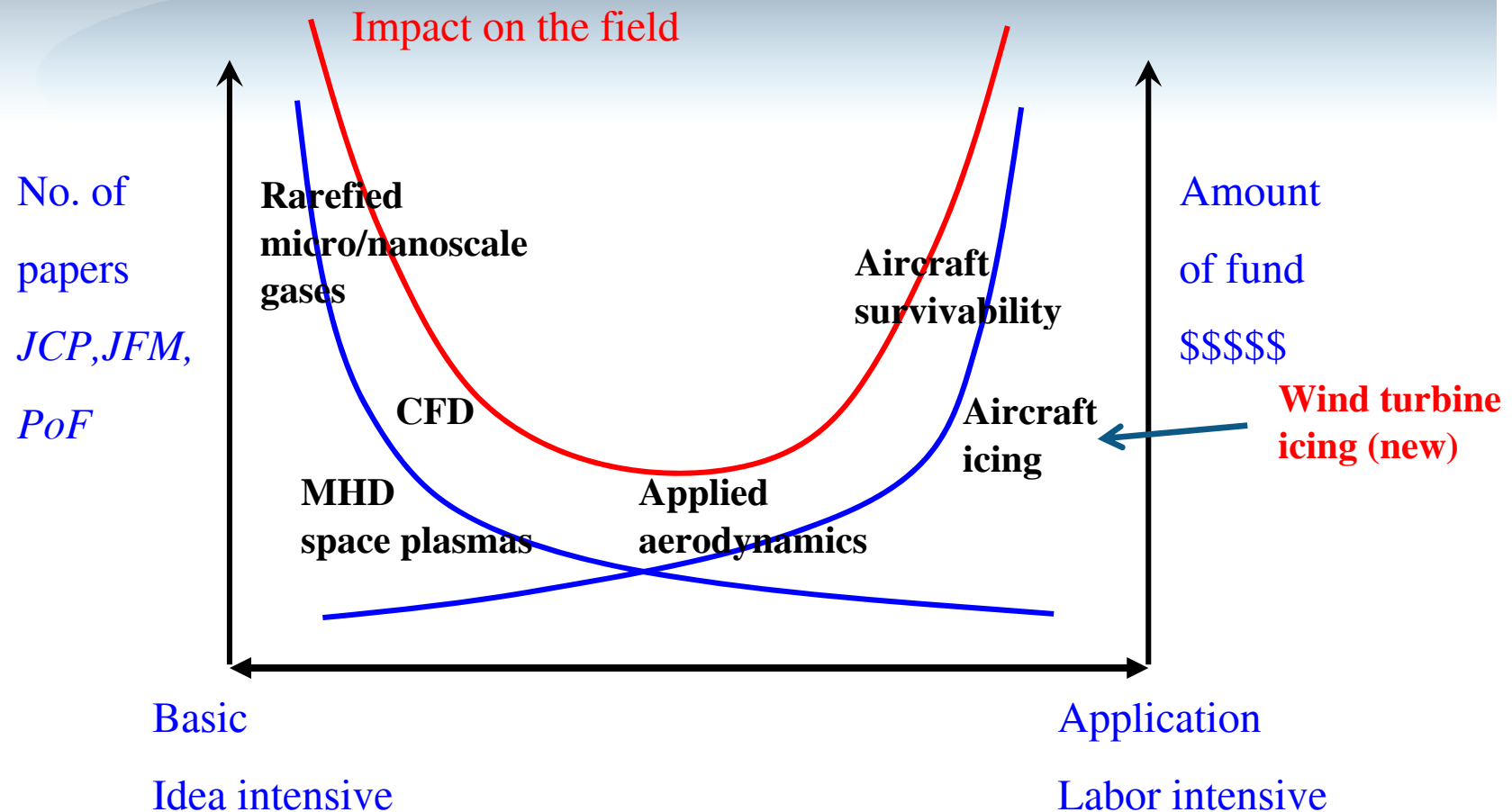**3 campus, 11 colleges, 67 divisions and departments**
23,000 students
730 full-time faculty members
Founded in 1948
Aerospace program (9 faculty; 172 undergraduates; 120 graduates)

Research Areas of Aerospace Comp. Modeling Lab

Impact on the field

No. of papers JCP, JFM, PoF

Amount of fund $$$$$

Rarefied micro/nanoscale gases

Aircraft survivability

CFD

Aircraft icing

Wind turbine icing (new)

MHD space plasmas

Applied aerodynamics

Basic

Application

Idea intensive

Labor intensive

Research Goal of ACML

Develop advanced computational models for rarefied (and micro/nano-scale) gases, aircraft icing and stealth upon which others can build efficient CFD/CHT & CEM codes
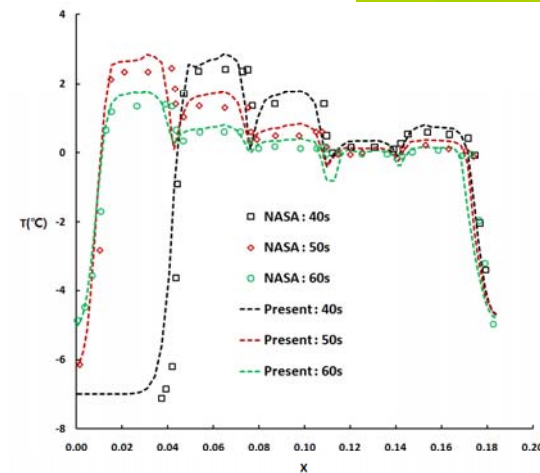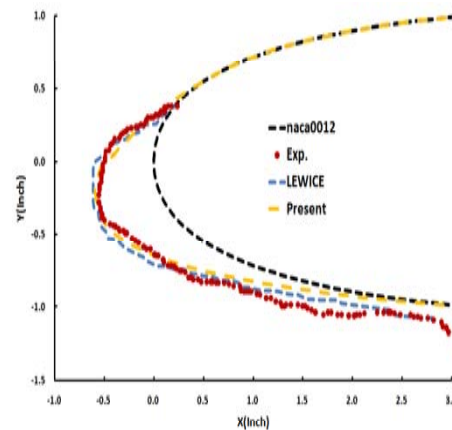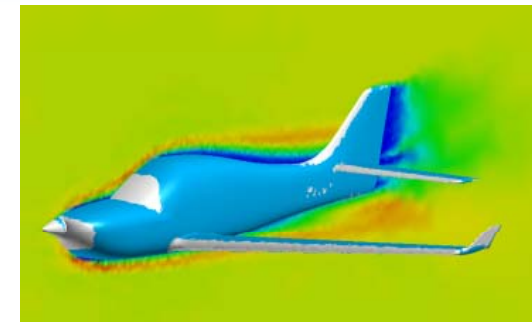
http://acml.gnu.ac.kr ⇨ \<Open knowledge\>

Previous Research Experiences in Aircraft Icing

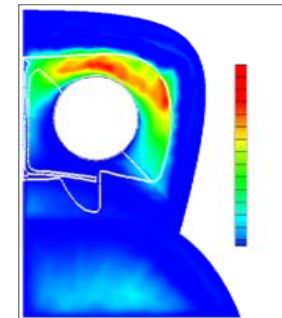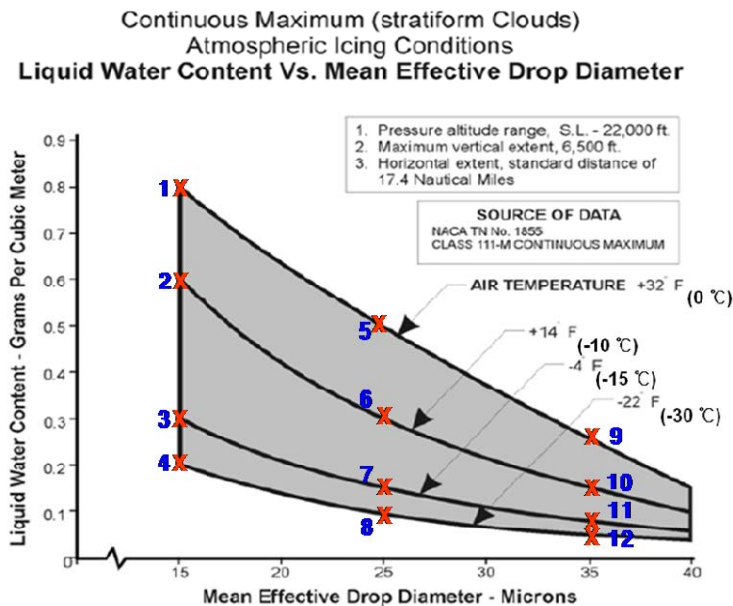- Research projects:

  항공기 표면발생 **Icing** 및 공력영향성 해석 (2008-2009; 국토해양부
  항공안전기술개발사업 – 한국항공우주산업㈜)

  Icing Analysis of Blade (2009-2010; 한국항공우주연구원

  한국형헬기 민군겸용구성품 개발사업)

Previous Research Experiences in Aircraft Icing

- Research project:

  Prediction of Intake Anti-Icing System of KUH by Using Numerical Analysis Method
  (2010-2012; 한국항공우주산업㈜)

Previous Research Experiences in Aircraft Icing

- International collaboration and professional course

## Effective Use of CFD for In-flight Icing Certification

In-flight ice formation on aircraft, rotorcraft, jet engines, UAV, detectors, antennae and optronics surfaces can significantly affect performance, handling qualities and safety. OEM or supplementary certification campaigns, long and tedious, can be greatly helped with modern icing CFD.

"Modern" icing CFD is defined as tools that are an extension of aerodynamic design and analysis technologies. Such an integrated aerodynamic/icing approach is proving itself a cost-effective *aid-to-design-and-to-certification* when made part of a well-structured compliance plan. Using "advanced and realistic" 3D simulations based on modern physical models allows a more comprehensive exploration of the combined aircraft/icing envelopes, optimized ice protection system design, and targeted/focused/reduced icing tunnel and flight tests. The end result is a more cost-effective and safer product that is easier to certificate.

This course presents the *state-of-the-art of icing CFD* by linking theory to applications. It is structured to be of equal interest to aerodynamics, icing, systems and flight simulation engineers, regulators and DERs.

Detailed knowledge of CFD is not essential. The lectures cover the major aspects of in-flight icing simulation: airflow, water impingement, ice accretion, anti-icing and de-icing calculations; handling quality issues; CFD-assisted certification.

The instructors bring a wealth of knowledge, as scientists who have produced codes in current use, practicing engineers who certify aircraft for major manufacturers, and former regulators who have closely monitored certification campaigns and have a deep understanding of safety issues.
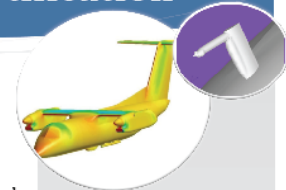
Information

Date | October 18 - 22, 2010
Location | Gyeongsang National University Jinju, South Korea
Cost | 1,500 US$ + applicable taxes
Registration | Using the registration form enclosed or on NTI web site
E-mail | events@newmerical.com
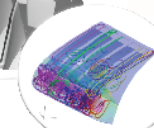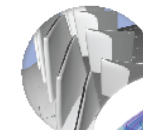Web site | www.newmerical.com

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McGill University

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Gyeongsang National University

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Bombardier Aerospace

Specialties of GNU ACML in Wind Turbine Icing

- Ice accretion on blades and its impact on performance

  - Code development

- Ice detectors and anti/de-icing systems

  - Survey

  - Computational analysis

- Mass imbalance due to ice accretion

  - Computational analysis

- Ice shedding

  - Methodology and associated algorithms

- Icing wind tunnel test

  - Consulting & virtual icing wind tunnel

Content

- Communities, journals, and textbooks

- CFD & icing glossary

- References

- Acknowledgement

- Lecture 1 Introduction to Icing in Aircraft and Wind Turbines (21 pages)

- Lecture 2 Physics of Wind Turbine Blades Icing and Performance Degradation (22 pages)

- Lecture 3 Numerical Modeling and CFD Simulation (50 pages)

- Lecture 4 Anti/De-icing System (31 pages)

Communities

- Conferences and societies

  Wind Power Conference & Exhibition

  European Wind Energy Conference and Exhibition (EWEC)

  BOREAS Conferences (Seven): Wind Turbine Operation in Cold Weather

  한국풍력에너지학회 http://kims.baraem.net/

  한국신재생에너지학회 http://www.ksnre.or.kr/

  Cf. Aircraft Icing

  SAE 2011 International Conference on Aircraft and Engine Icing and Ground Icing, Chicago, June, 2011. (Next 2015)

Journals

- Journals

  Cold Regions Science and Technology

  Renewable and Sustainable Energy Reviews

  Renewable Energy

  International Journal of Offshore and Polar Engineering

  Journal of Wind Engineering and Industrial Aerodynamics

  Wind Engineering

  Wind Energy

- Textbooks

  Wind Energy Explained: Theory, Design and Application
    (J. F. Manwell et al.; Wiley; 2010)

  Wind Energy Handbook (T. Burton et al.; Wiley & Sons; 2001)

  Aerodynamics of Wind Turbines (M. O. L. Hansen; Earthscan; 2008)

CFD & Icing Glossary

- CFD (Computational Fluid Dynamics)

  Navier-Stokes-Fourier equations;

  Lagrangian & Eulerian;

  Dimensionless numbers (Re & M);

  Discretization (grid), consistency (truncation error), stability (Courant-Friedrichs-Lewy condition)

- Icing

  Air speed, anti-icing, critical surface, cumulous clouds;

  De-icing, freezing rain, glaze ice, liquid water content (LWC; g/m^3), median volumetric diameter (MVD; micron);

  Residual ice, rime ice, runback, stratus clouds, supercooled (until -40C), supercooled large droplets (SLD; MVD>50micron);

  Temperature inversion, stagnation temperature

  Appendix C, D, O (for aircraft icing)

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- An, Y.G., A Study of Scaling Technique for Icing Wind Tunnel Test, *GNU M.S. Thesis*, August, 2011.

- Jung, S.K., Myong, R.S. and Cho, T.H., Efficient Prediction of Ice Shapes in CFD Simulation of In-flight Icing Using a POD-Based Reduced Order Model, *SAE 2011 International Conference on Aircraft and Engine Icing and Ground Deicing*, 2011-38-0032.

- Jung, S.K., Shin, S.M., Myong, R.S., Cho, T.H., An Efficient CFD-Based Method for Aircraft Icing Simulation Using a Reduced Order Model, *Journal of Mechanical Science and Technology*, Vol. 25, No. 3, pp. 703-711, 2011.

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  Ahn, Kook Bin

- GNU SDCAE (Structural Design/Dynamics & CAE) Laboratory

  Kim, Dong Hyun, Associate Prof.

  Kim, Yo Han, Graduate Student

You Need Cooling?

You Need Cooling?

You Need Cooling or Heating?