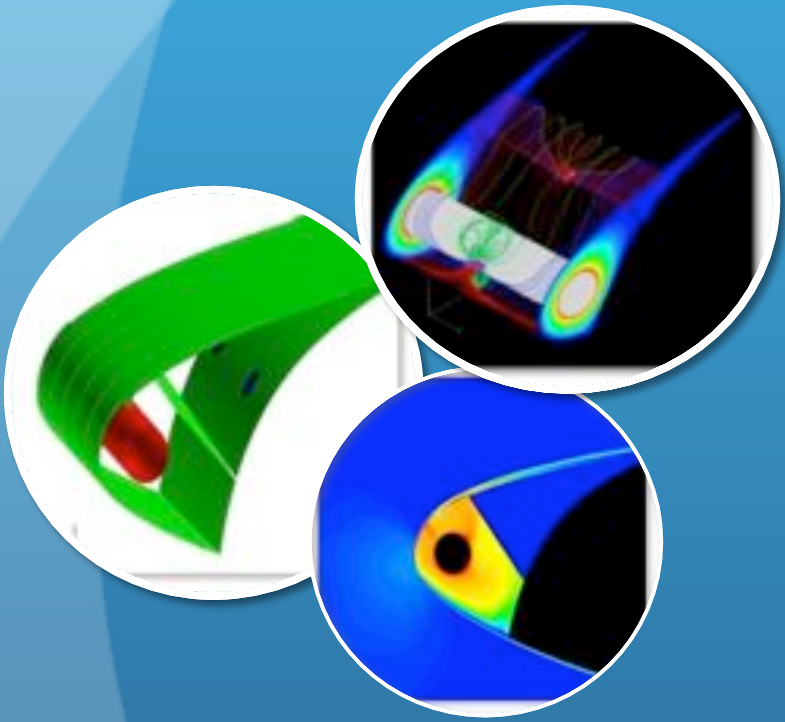
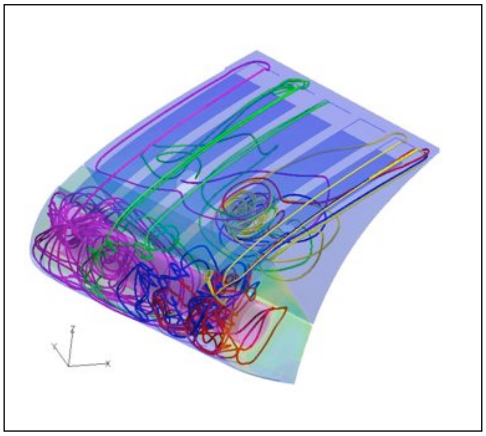
newmerical
TECHNOLOGIES INT.



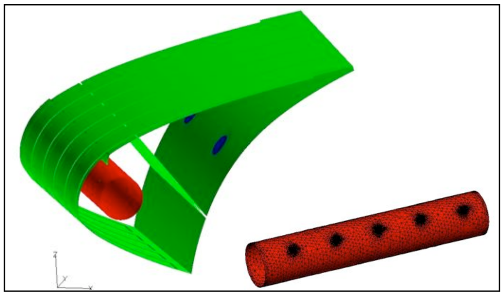
CHT3D

Modern Capabilities for the Design and Analysis of Hot-air / Electro-thermal Anti-icing and De-icing IPS



In 2008, do you still design de-icing systems based on 2D analysis? Could you, based on the accompanying figure, be convinced that the flow is indeed 2D inside the wing or nacelle? Do you, in 2008, use 1980's methodologies based on empirical heat transfer correlations? Are these correlations for the exact geometries you are using, or are they for flat plates? Why is your Aerodynamics Department relying on 3D CFD analysis, but your icing department is content with 2D heuristic methods?

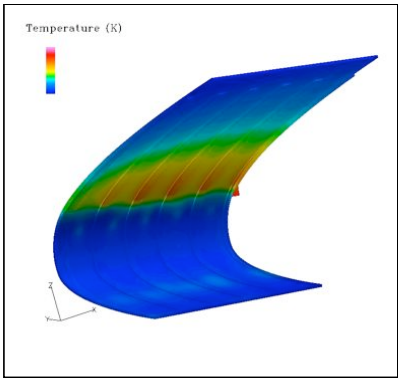
In the era of CFD, it is now possible to piggyback on existing CFD analyses and design hot air anti-icing systems in a verifiable, reliable manner, totally integrated with Aerodynamics. A modest investment at design time can lead to more effective systems that will pass certification faster, sustain less in-service problems and minimize post-certification adjustments or flight limitations.



In hot-air systems, hot bleed air from the engine is ducted through perforated tubes to impinge on the inner skin surface. Several parameters affect the performance of high velocity jets: number of holes, size of holes, hole pattern, supply temperature and pressure, internal geometry of the wing or nacelle and ducting layout. FENSAP-ICE enables the designer to optimize all the aforementioned parameters, in order to provide the most cost-effective anti-icing, thus reducing the demand on bleed air.

FENSAP-ICE comprises 4 interconnected truly 3D modules driven by a highly intuitive Graphical User Interface: the FENSAP flow solver (accurate CFD, with OptiGrid anisotropic mesh adaptation), the DROP3D droplet impingement, the ICE3D ice accretion and shape, the CHT3D conjugate heat transfer modules. The system enables aircraft designers to comprehensively analyze the supercooled water droplets icing environments of Appendix C, and also SLD.

The FENSAP-ICE anti-icing process starts by solving the external flow field via FENSAP, based on flight parameters. FAR 23, 25, or 27 Appendix C requirements then guide water-catch studies through DROP3D, at various altitudes, airspeeds, incidences and droplet sizes, representative of the range of hold conditions. An energy balance calculation, along with the engine cycle for a given flight condition, determines the sizing condition, i.e. the largest energy deficit or smallest energy margin. The impingement limits and locations of maximum collection efficiency help determine the jet impingement angle in the design of piccolo holes' pattern.



Once a hole size, number of holes, and pattern are selected, an internal mesh is generated from a CAD model, and a flow solution is obtained using FENSAP. CHT3D then links the internal flow to the external one and ICE3D through the solid skin, to iteratively determine the skin temperature and heat flux distributions. The process is based solely on the solution of the exact Navier-Stokes equations and totally avoids empiricism.

The temperature, water film thickness and ice accretion rate on the external skin surface, then determine the anti-icing state (iced-up, or running-wet, or fully-evaporative; for example the figure shows a region fully evaporative region and an adjacent running-wet one), the potential for "runback refreeze" on unprotected surfaces, and indicate the overall effectiveness of the hot air anti-icing system design. The piccolo holes' pattern can then be adjusted for a new design cycle until the desired ice protection is reached.

An example of a recent study for an important jet engine company has blindly compared FENSAP-ICE with icing tunnel results for anti-icing of a nacelle. The following table gives temperatures, for two cases, at several locations from the outer barrel to the inner barrel. The mean of all skin temperature differences is about 5^{o}K.

TEMPERATURE DIFFERENCE ($D = T_{NUM} - T_{EXP}$) °K

Location	1	2	3	4	5	6	7	8	9	10
Case 1	-2	-7	-13	-9	3	3	0	-4	-3	-4
Case 2	0	-3	-5	-9	-7	-8	-7	-6	-4	-6

Newmerical Technologies' strategic focus is in-flight icing, and its ongoing fundamental research has guaranteed its customers a technological edge through a continuous timely generation of new features and capabilities.

All CFD images produced by FieldView

newmerical
TECHNOLOGIES INT.

Newmerical Technologies International (NTI) develops and markets advanced CFD software and offers flow simulation services in the aerospace, architectural, automotive and marine markets. Newmerical is the acknowledged world leader for in-flight icing simulation and related services.

Canada Newmerical Technologies International
Mr. Martin Aubé, Vice-President Operations
680 Sherbrooke Street West, 7th Floor, Montreal, QC, CANADA H3A 2M7
+1 (514) 398-2671, martin.aube@newmerical.com

USA Newmerical Technologies International
Dr. Dennis Torok, General Manager
1229 Cedar Lake Road South, Minneapolis, MN 55416, USA
+1 (612) 374-3495, NTIUSA@newmerical.com

France, Italy, Belgium, Spain FLUOREM
Dr. Macoumba N'Diaye
Centre Scientifique Auguste Moiroux, 64 Chemin des Mouilles, 69130 Ecully Cedex, FRANCE
+33 (0) 4 78 33 99 35, mndiaye@fluorem.com

Switzerland, Germany, Scandinavia, Eastern Europe CFS Engineering
Dr. Elizabeth Mickaily-Huber
PSE-A, 1015 Lausanne, SWITZERLAND
+41 21 693 8469, huber@cfse.ch

Japan Y-MAX Inc.
Mr. Tetsushi Nishida, President
5-2-16, B-1F Tsurumaki, Setagaya-ku Tokyo 154-0016, JAPAN
+81 3 5451-0085, tetsu@y-max.co.jp

China Beijing Vision Strategy Technology Ltd.
Mr. Jack Zheng, President
Suite 1102, Tower C, Triumphal City, 170 Beiyuan Rd,
Chaoyang District, Beijing 100101, PEOPLE'S REPUBLIC OF CHINA
+86 10 5927-3211, jack.zheng@visionstrategy.com.cn

Korea Altsoft, Inc.
Mr. JaeYeon Lee
A-plus House 2F, 36-6 Samsung-Dong, Kangnam-Gu Seoul 135-090, KOREA
+82 (0)2 547-2344, lee.jy@altsoft.co.kr

www.newmerical.com