Representative Current and Recent Research Projects

Fluid Mechanics Laboratory

Director: Professor S. Tavoularis

uOttawa

L'Université canadienne
Canada's university

Université d'Ottawa | University of Ottawa

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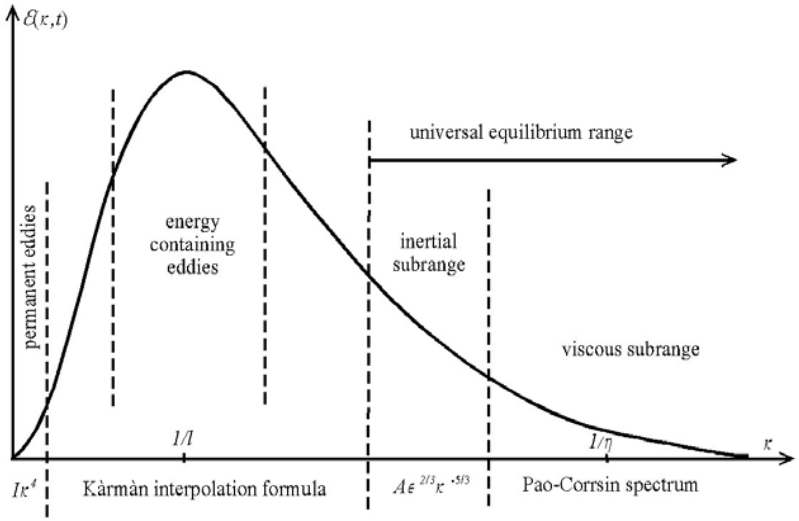
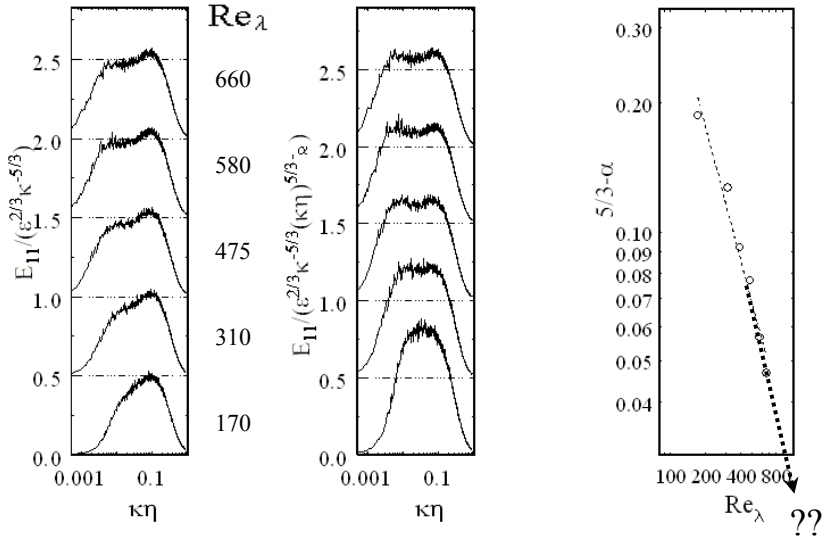
The fine structure of turbulence

Researcher: Mohsen Ferchichi, Ph.D. Student

Funding: NSERC





The energy spectrum of turbulence

<u>Kolmogorov's 2nd hypothesis:</u>

For high Re_λ, there is an *inertial spectral range* such that

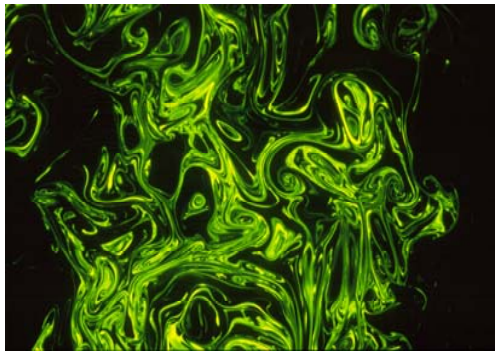
$$E(\kappa) = C\,\varepsilon^{2/3}\,\kappa^{-5/3}$$

The fine structures of temperature and concentration fields

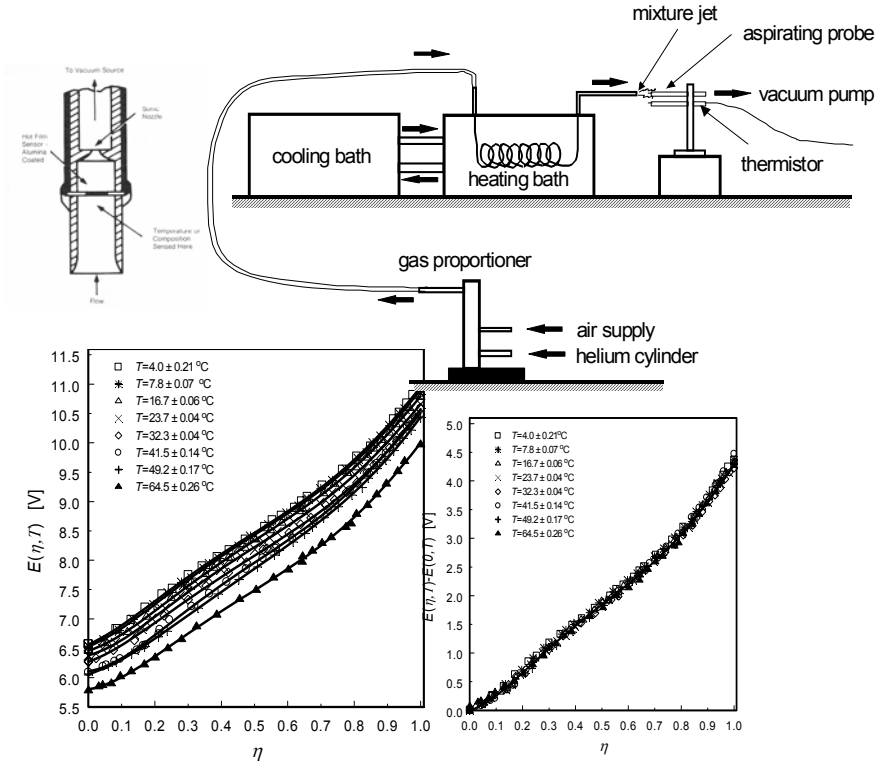
Researchers: Mohsen Ferchichi, Sebastian Marineau-Mes, Ph.D. Students; Tony Standbridge, M.A.Sc. Student; Melanie Cabannes, Diploma Thesis, Visiting from ESIP, France

Funding: NSERC

Four-sensor cold-wire probe:
0.7 μm dia, 0.5 mm length



Mixing of fluorescent dye in homogeneous turbulence



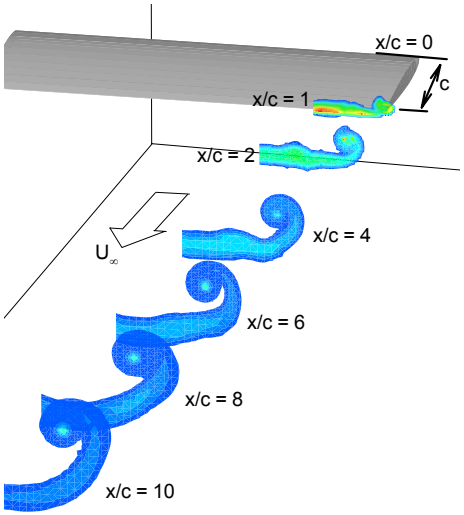
Sonic-nozzle aspirating probes in non-isothermal gas mixtures

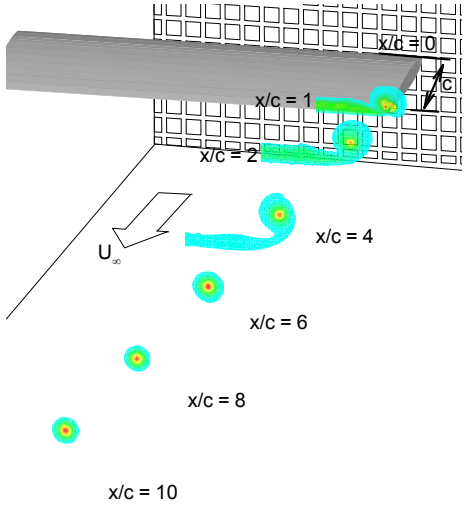
Interaction of a wing-tip vortex and free-stream turbulence

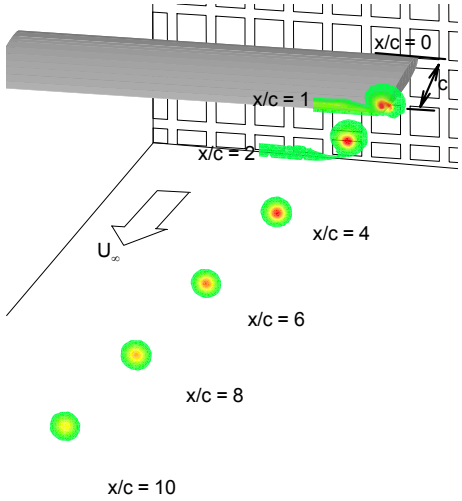
Researchers: Sean Bailey, Ph.D. Student; Semi Zamouri, Diploma Thesis, Visiting from ESSTIN, France

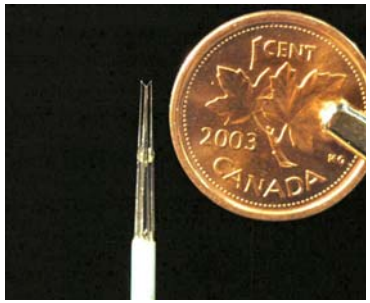
Collaboration: Dr. B.H.K. Lee, IAR, NRC

Funding: NSERC







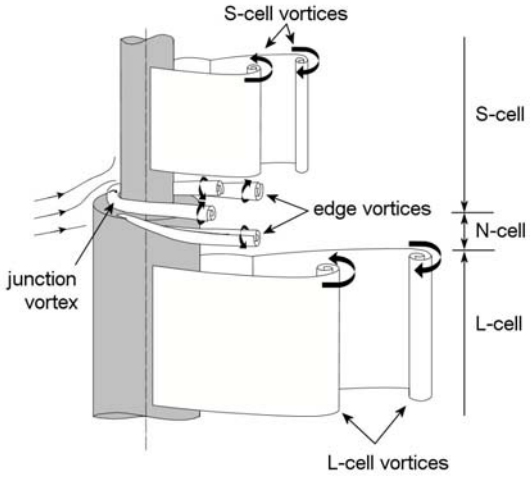


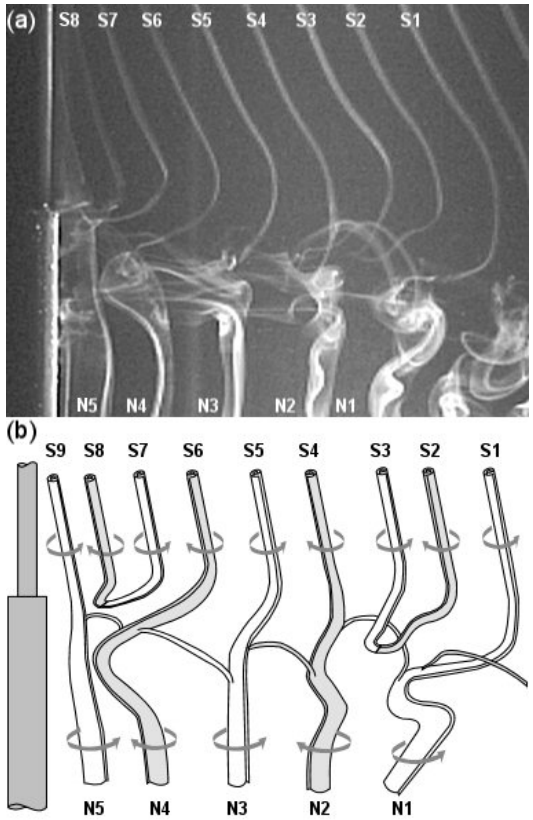
Four-sensor vorticity and velocity vector probe

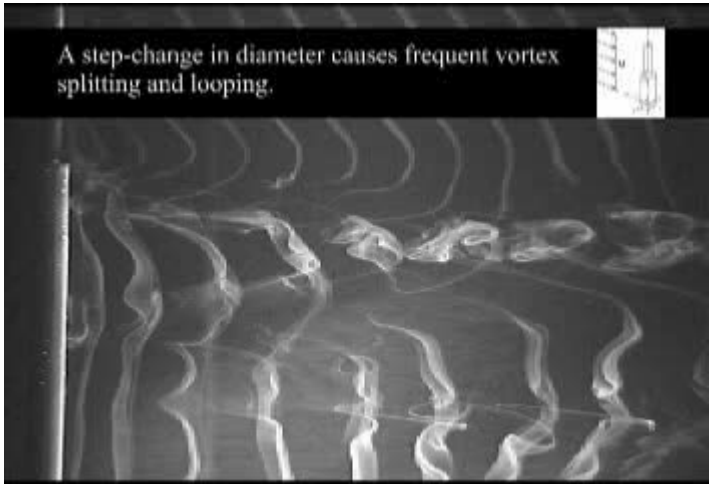
Vortex shedding from complex objects

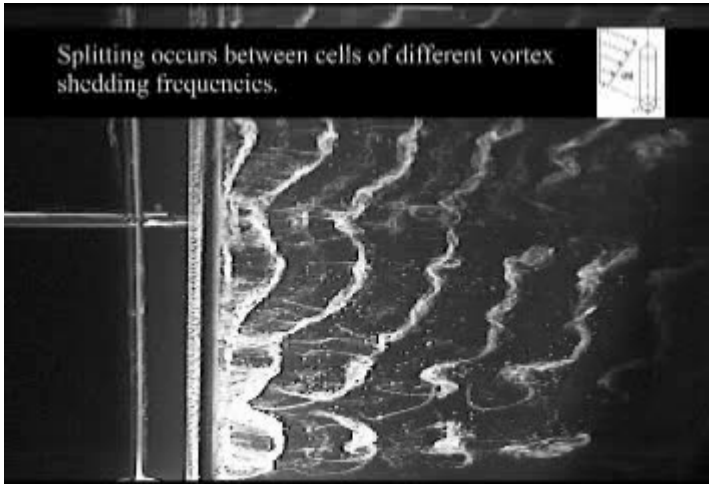
Researcher: Warren Dunn, Ph.D. Student

Funding: NSERC









Vortex structure in low-momentum, elevated jets in cross-flow

Researcher: Andrew Cameron, M.A.Sc. Student

Collaboration: Professor Matthew Johnson, Carleton University

Funding: NSERC

Flow visualization using conventional dye

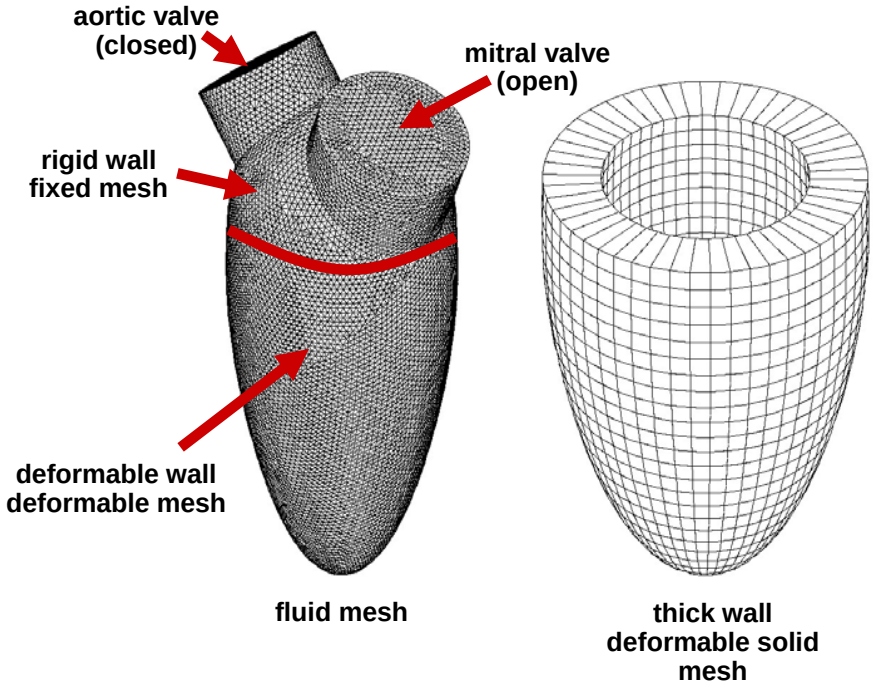
Flow visualization using fluorescent dye

Simulation of blood flow and wall motion in the canine heart ventricles

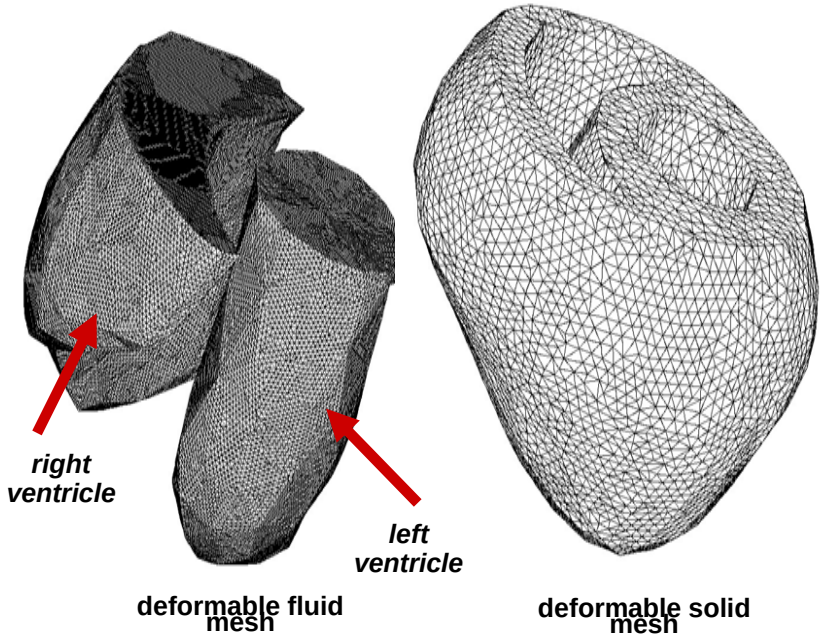
Researcher: Matthew Doyle, Ph.D. Student

Collaboration: Professor Yves Bourgault

Funding: NSERC



Idealized geometry



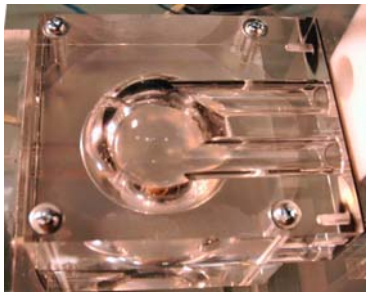
Anatomically realistic geometry

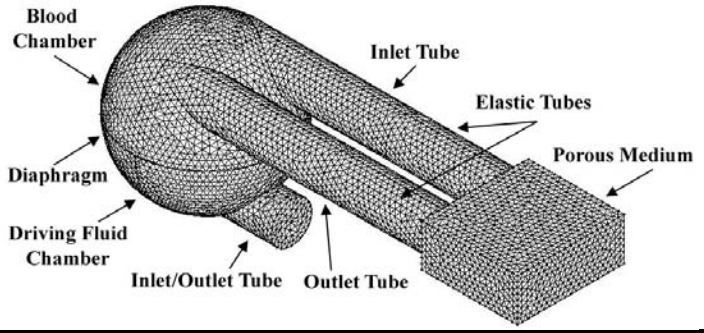
Blood flow in idealized ventricular assist devices

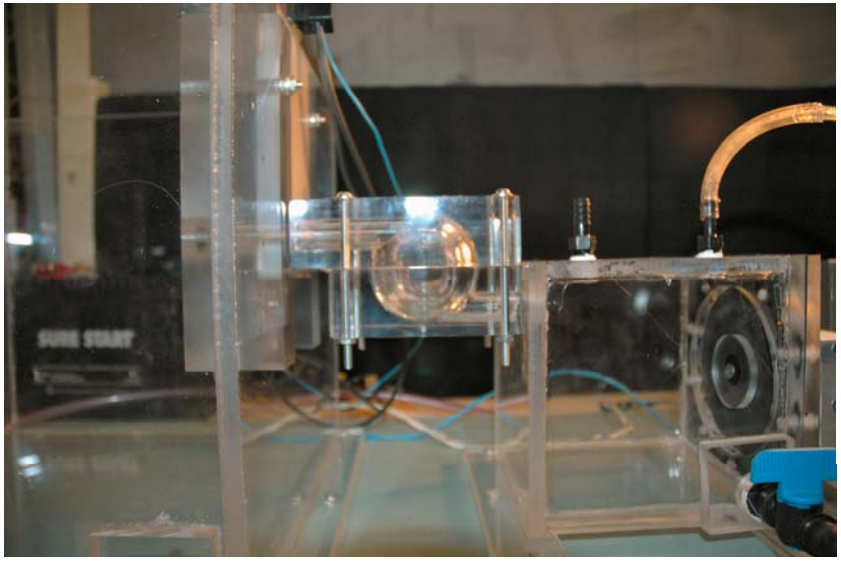
Researchers: Matthew Doyle, Michael Paciocco, M.A.Sc. Students; Jean-Baptiste Vergniaud, Diploma Thesis, Ecole Polytechnique, France; Guillaume Desjardins, NSERC Summer Student

Collaboration: Professor Yves Bourgault

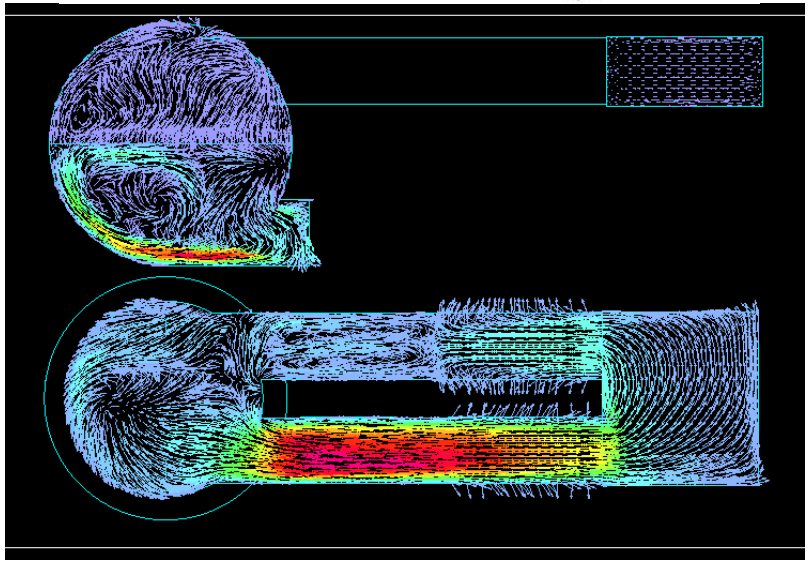
Funding: NSERC







Experimental model



Numerical simulations with fluid-structure interaction

Optimal control of flow in artificial hearts

Researchers: Akbar Sahrapour, Ph.D. Student; Dr.Aziz Madrane, Postdoctoral Fellow

Collaboration: Professor N. Ahmed

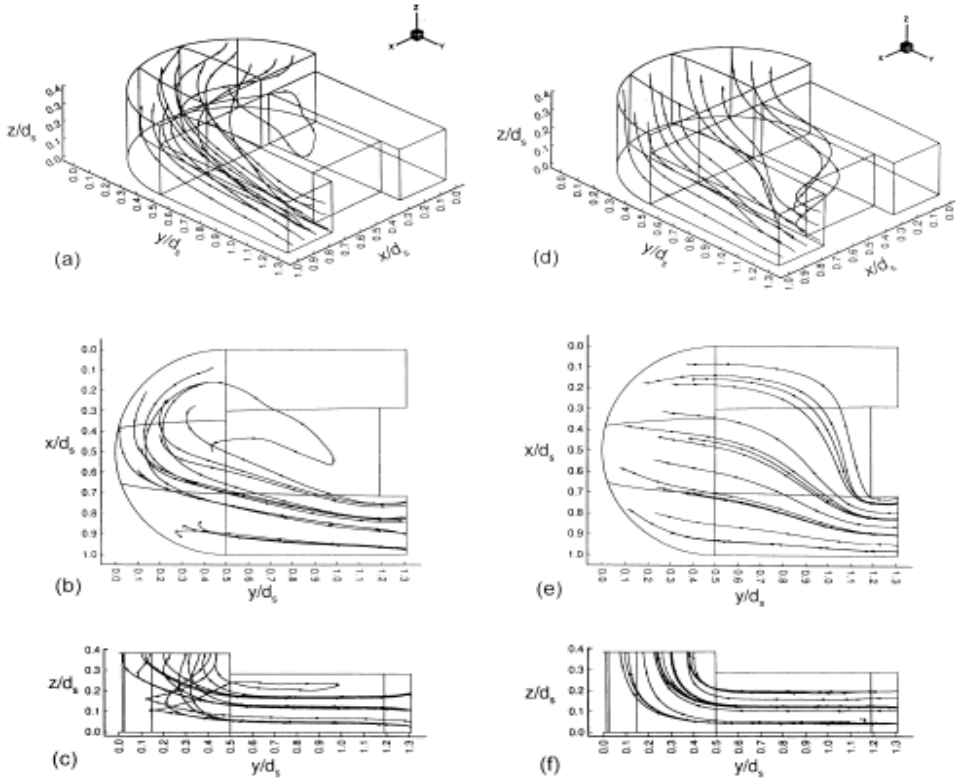
Funding: NSERC

$$
\begin{cases}
\dfrac{\partial \mathbf{u}}{\partial t} + (\mathbf{u}\cdot\nabla)\mathbf{u} - \dfrac{1}{Re}\nabla^2\mathbf{u} + \nabla p = \mathbf{f} \quad \text{in } \Omega\times(0,T], \\
\nabla\cdot\mathbf{u} = 0 \quad \text{in } \Omega, \\
\mathbf{u}|_{t=0} = \mathbf{u}(\mathbf{x},0) = 0 \quad \text{in } \Omega, \qquad \mathbf{u}|_{\Gamma_m} = \mathbf{g}(\mathbf{x},t). \qquad \mathbf{u}|_{\Gamma_f} = 0, \\
\mathbf{u}|_{\Gamma_i} = 0, \qquad \left.\dfrac{\partial \mathbf{u}}{\partial \mathbf{n}}\right|_{\Gamma_o} = 0, \qquad 0 < t \le T_1, \\
\left.\dfrac{\partial \mathbf{u}}{\partial \mathbf{n}}\right|_{\Gamma_i} = 0, \qquad \mathbf{u}|_{\Gamma_o} = 0, \qquad T_1 < t \le T,
\end{cases}
$$

$$
\begin{aligned}
J(\mathbf{u},\mathbf{g}) \;=\; & \frac{\alpha_s}{2}\int_I\int_\Omega |\nabla\mathbf{u}(\mathbf{x},t)|^2\,d\mathbf{x}\,dt + \frac{\alpha_v}{2}\int_I\int_\Omega |\nabla\times\mathbf{u}(\mathbf{x},t)|^2\,d\mathbf{x}\,dt \\
& + \frac{\alpha_e}{2}\int_I\int_{\Gamma_m} |\mathbf{g}(\mathbf{x},t)|^2\,ds\,dt,
\end{aligned}
$$

$$
\begin{cases}
-\dfrac{\partial \mathbf{z}^0}{\partial t} - (\mathbf{u}\cdot\nabla)\mathbf{z}^0 + (\nabla\mathbf{u})^T\mathbf{z}^0 - \dfrac{1}{Re}\nabla^2\mathbf{z}^0 + \nabla q_z^0 = \mathbf{G}^1(\mathbf{u}^0,\mathbf{g}^0) \quad \text{in } \Omega\times(0,T], \\
\nabla\cdot\mathbf{z}^0 = 0 \quad \text{in } \Omega, \\
\mathbf{z}^0|_{t=T} = \mathbf{z}^0(\mathbf{x},T) = 0 \quad \text{in } \Omega, \qquad \mathbf{z}^0|_{\Gamma_m} = 0, \qquad \mathbf{z}^0|_{\Gamma_f} = 0, \\
\mathbf{z}^0|_{\Gamma_i} = \lambda(Q^0 - Q^d), \qquad \mathbf{z}^0|_{\Gamma_o} = 0, \qquad 0 < t \le T_1, \\
\mathbf{z}^0|_{\Gamma_i} = 0, \qquad \mathbf{z}^0|_{\Gamma_o} = \lambda(Q^0 - Q^d), \qquad T_1 < t \le T;
\end{cases}
$$

Equations of motion, cost functional and adjoint equations



Non-optimal flow

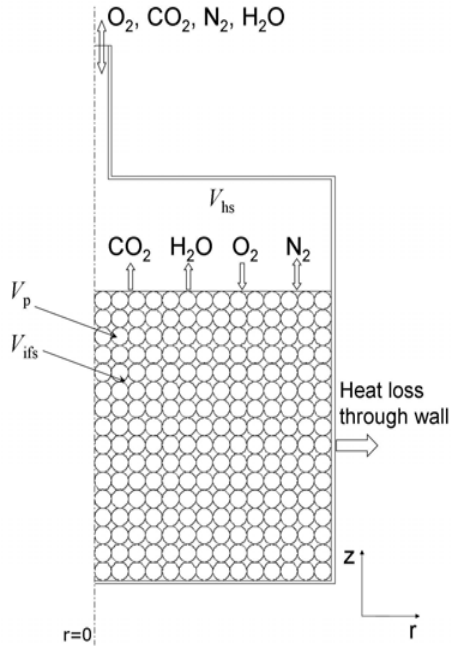
Optimal flow

Mathematical/numerical modeling of perforation-mediated modified atmosphere packaging

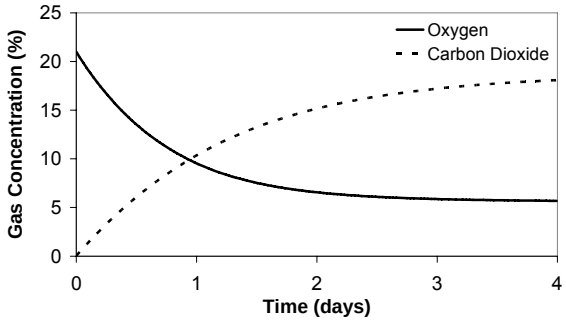
Researcher: Dr. Timothy Rennie, NSERC Postdoctoral Fellow

Funding: NSERC

- Diffusion channel and headspace
  - Navier-Stokes equations
  - Stefan-Maxwell equations
  - Energy equation
- Product mass (fruit and inter-fruit space) treated as porous medium
  - Brinkman equations
  - Stefan-Maxwell equations
  - Energy equation for heat transfer
  - Respiration and transpiration equations
  - Condensation on fruit and outer wall
- Equations solved using COMSOL Multiphysics™



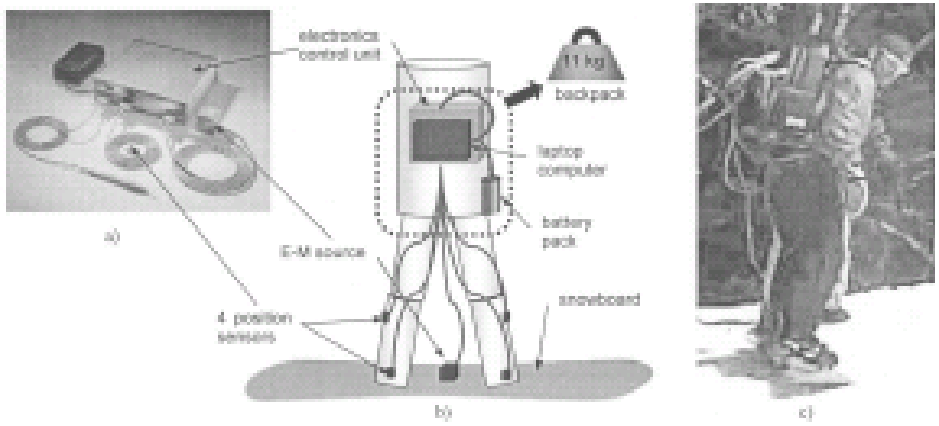
Changes in gas composition for modified atmosphere packaged strawberries at 7°C

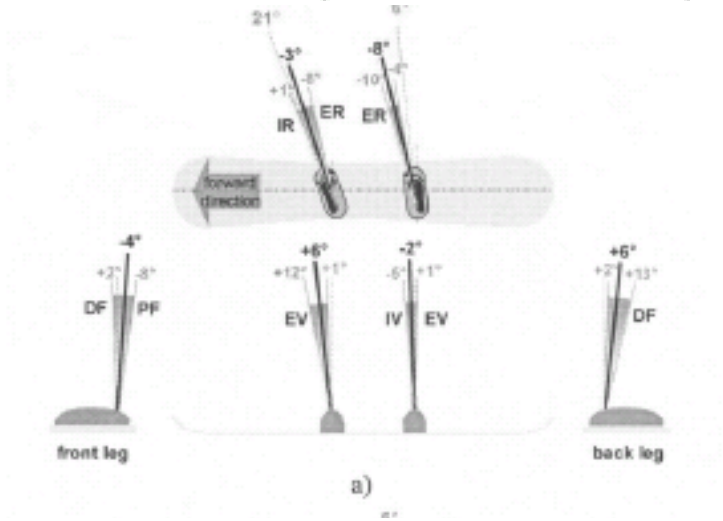


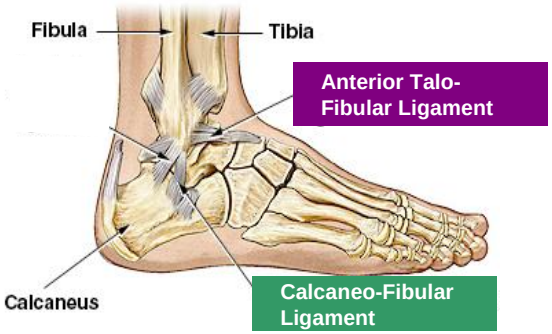
Kinematics of the ankle joint complex in snowboarding

Researcher: Sébastien Delorme, Ph.D. Student

Collaboration: Professor Mario Lamontagne



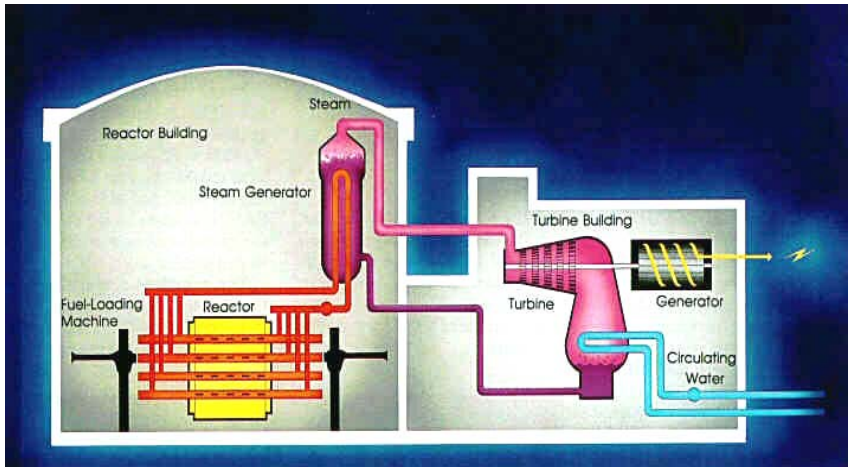




Coherent structures and coolant transport in nuclear reactor rod bundles

Researchers: Sadok Guellouz, Dongil Chang, Ph.D. Students; Floryan Baratto, Diploma Thesis, Visiting from ENSHMG, France

Funding: AECL, NSERC

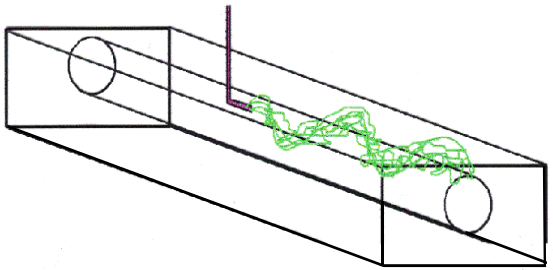


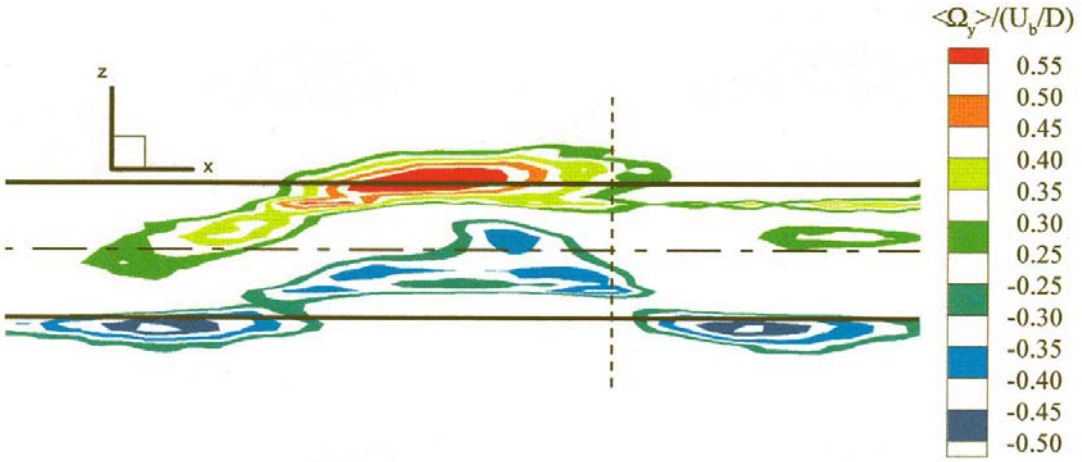
The CANDU nuclear reactor

Experimental identification of coherent structures in a single-rod channel

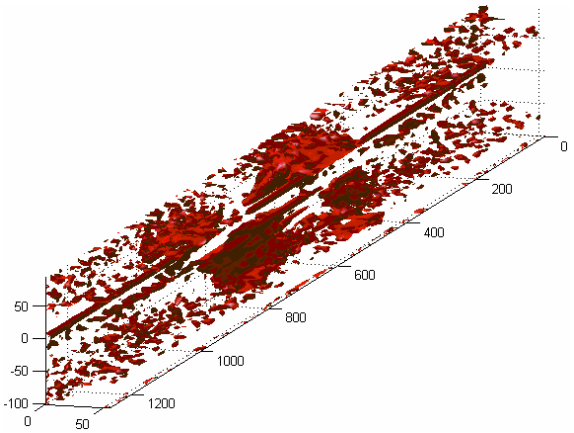
- Multiple-sensor hot-wire probes
- Identification of structure by triggering probe
- Conditional sampling of traversed probe
- Phase-averaging to obtain average structure
- Decomposition to coherent and non-coherent parts

smoke injection



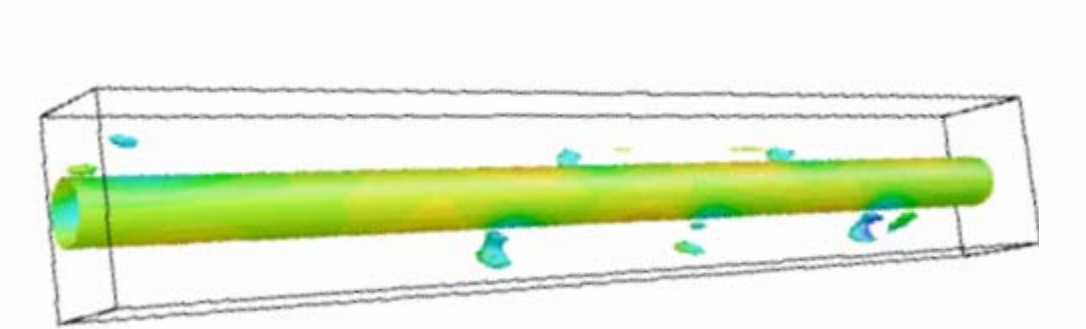


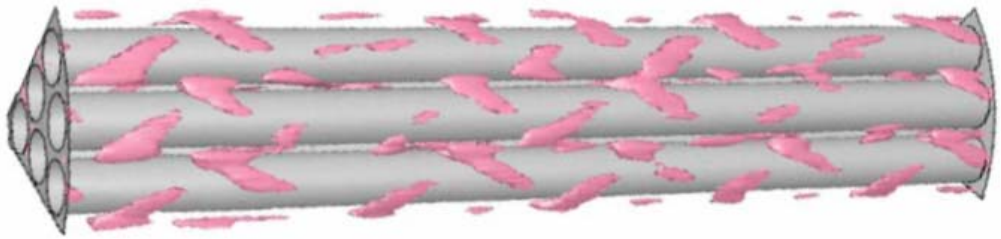
Vorticity contours of phase-averaged coherent field

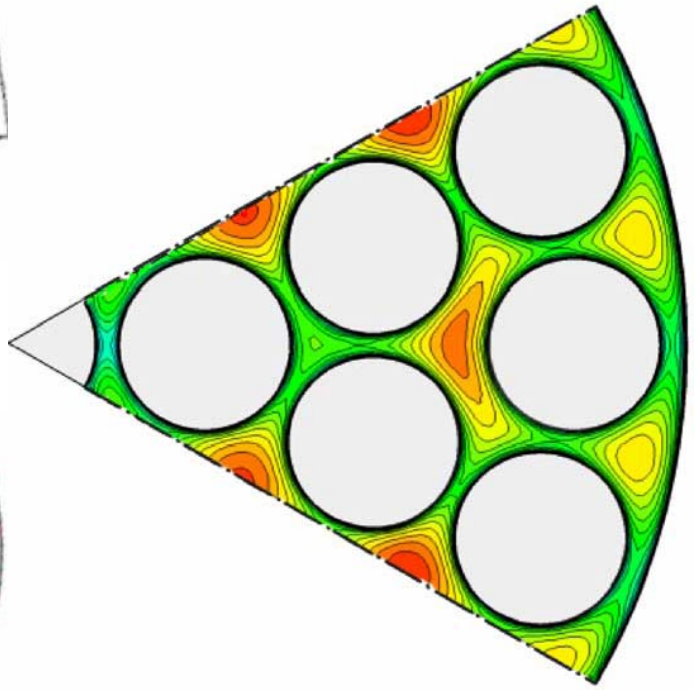


Numerical identification of coherent structures in a single-rod channel and in a 37-rod bundle

- High-resolution, unsteady RANS
- Reynolds Stress Model
- Coherent structure identification with *Q* criterion





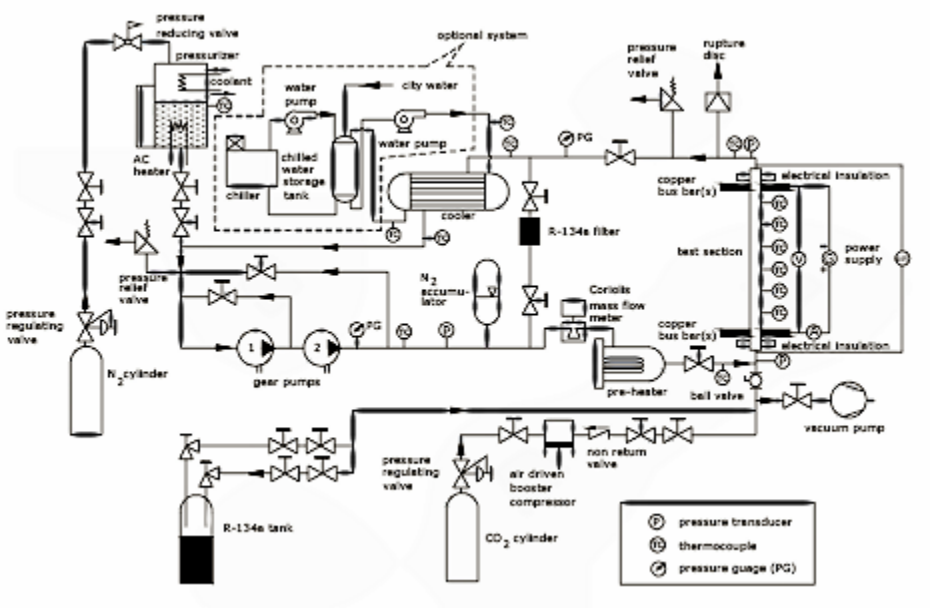


Experimental and analytical thermalhydraulic studies of supercritical flows in tubes, annuli and rod bundles

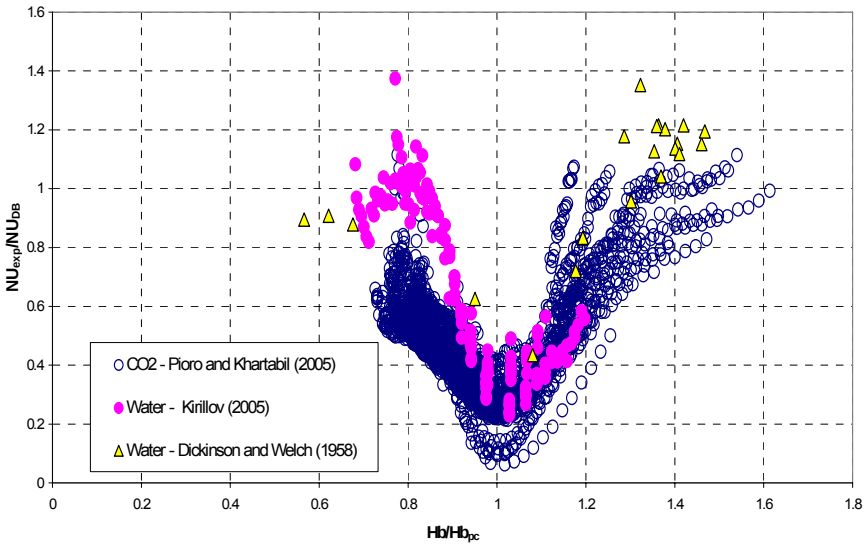
Researcher: Prasada Rao Gudla, Ph.D. Student

Collaboration: Professor D. Groeneveld

Funding: AECL, NRCan



Preliminary design of multi-fluid supercritical flow loop

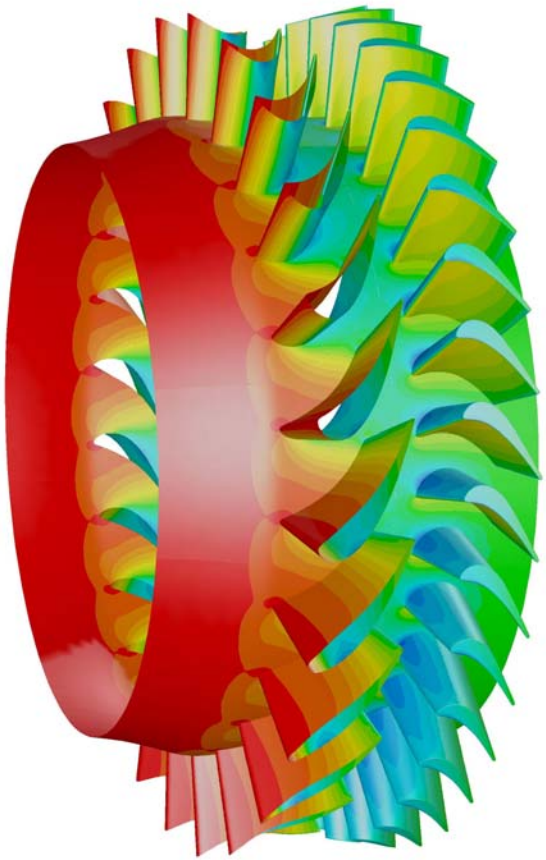


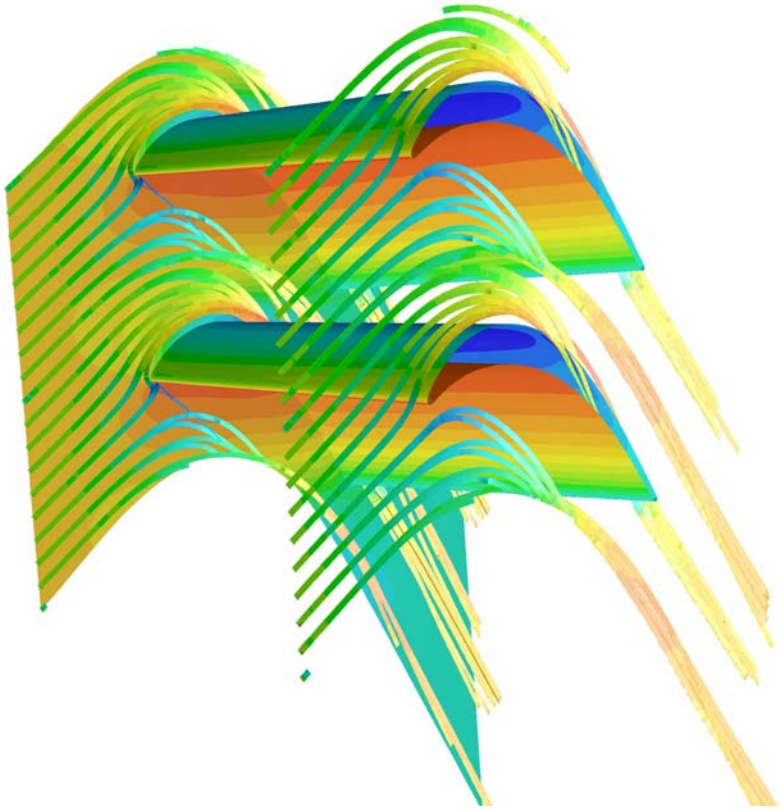
Similarity of supercritical heat transfer in water and surrogate fluids

Unsteady CFD Simulations and Design Criteria for High Pressure Gas Turbine Stages

Researchers: Dr. Dongil Chang, Research Associate; Derek Lastiwka, Craig Smith, M.A.Sc. students

Funding: Pratt and Whitney Canada, NSERC



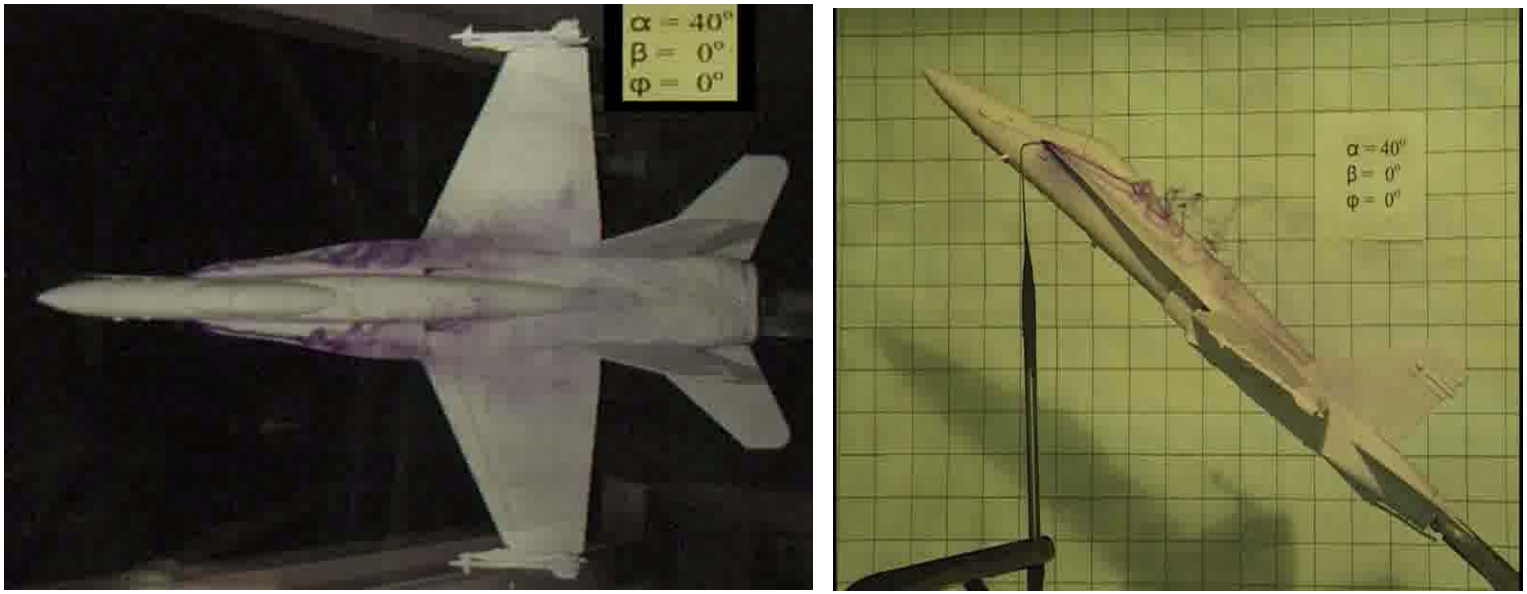


Bursting of LEX vortices and loading of the CF-18 tail fins

Researchers: S. Marineau-Mes, Ph.D. Student; Andrew Woronko, Co-op Student

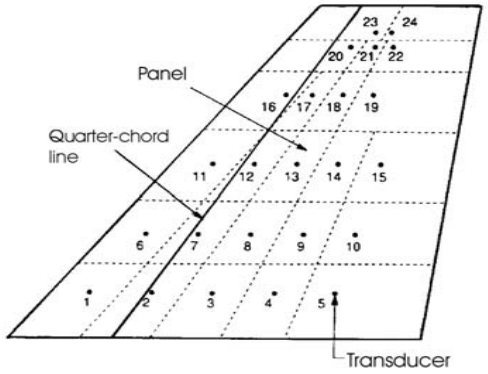
Collaboration: Dr. B.H.K. Lee, IAR, NRC

Funding: DND, NRC, NSERC

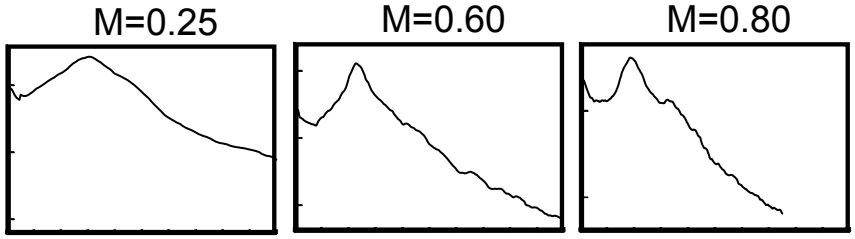


Water-tunnel flow visualization

Tests at IAR Trisonic Wind Tunnel
National Research Council, Ottawa



24 pressure transducers per side
Instantaneous measurements:
normal force, bending moment,
torsion moment



power spectra (α=30°)

near-periodicity of loading / vortex breakdown / coherent structure generation

Mach number M = 0.25, 0.60, 0.80

pitch angle: α = 25°, 30°, 32.5°

sideslip angle: -15° $\leq \beta \leq$ 15°

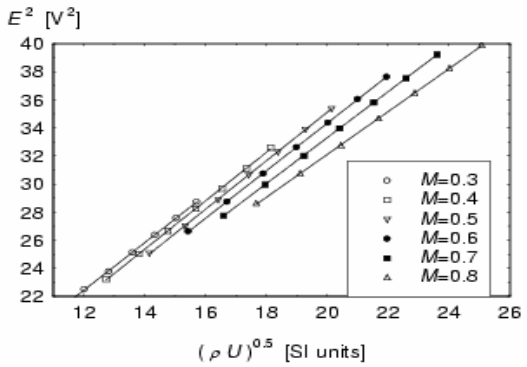
roll angle: -30° $\leq \varphi \leq$ 30°

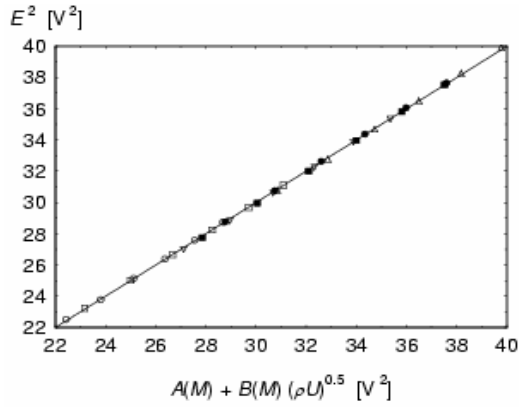
Hot-wire anemometry in high subsonic and transonic flows

Researchers: Roch Vaillancourt, Christopher Kirney, Master's Students

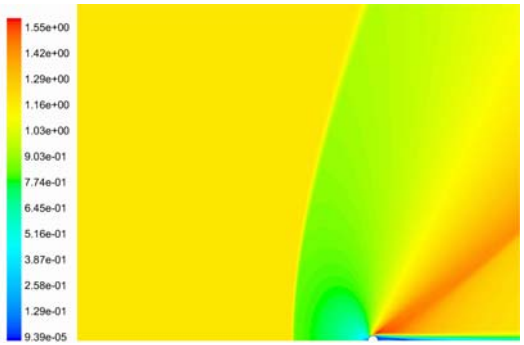
Collaboration: Dr. Fenella De Souza, IAR, NRC

Funding: NSERC, NRC

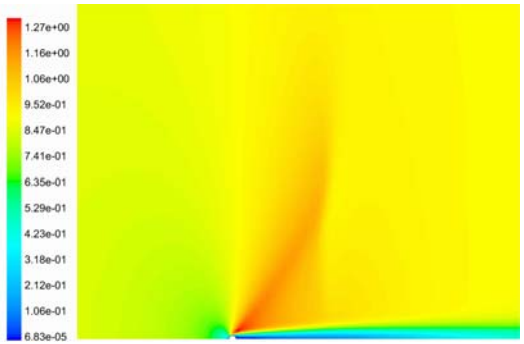




$$E^2 = A(M, T_0) + B(M, T_0)(\rho U)^n$$



Mach number contours, M_∞=1.2



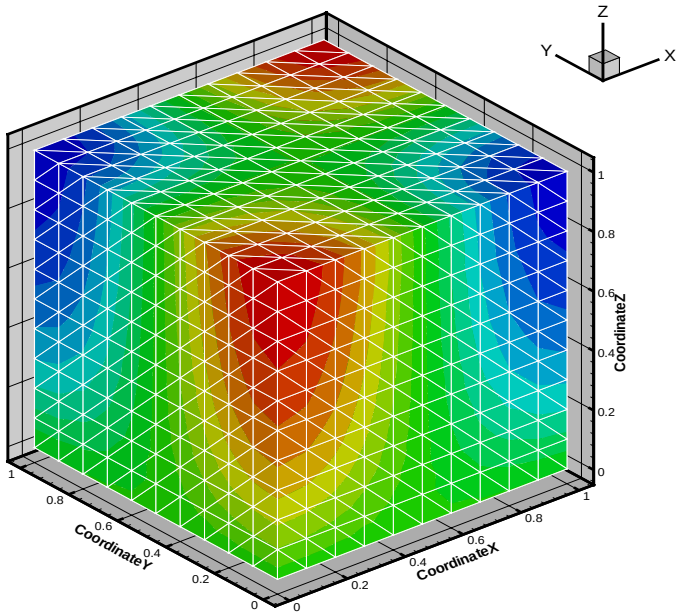
Mach number contours, M_∞=0.9

Space-time mesh adaptation

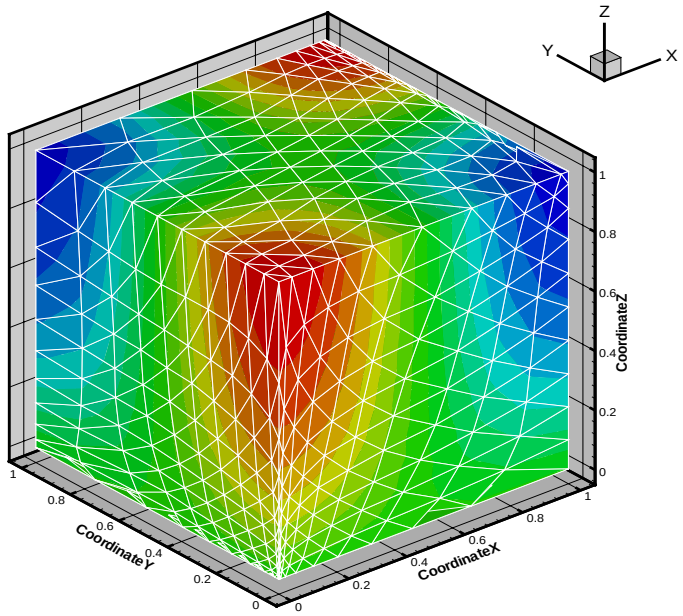
Researcher: Pascal Tremblay, Ph.D. Student

Collaboration: Professor Yves Bourgault

Funding: NSERC



Original mesh



Adapted mesh