Enabling New Applications with CONVERGE v3.0

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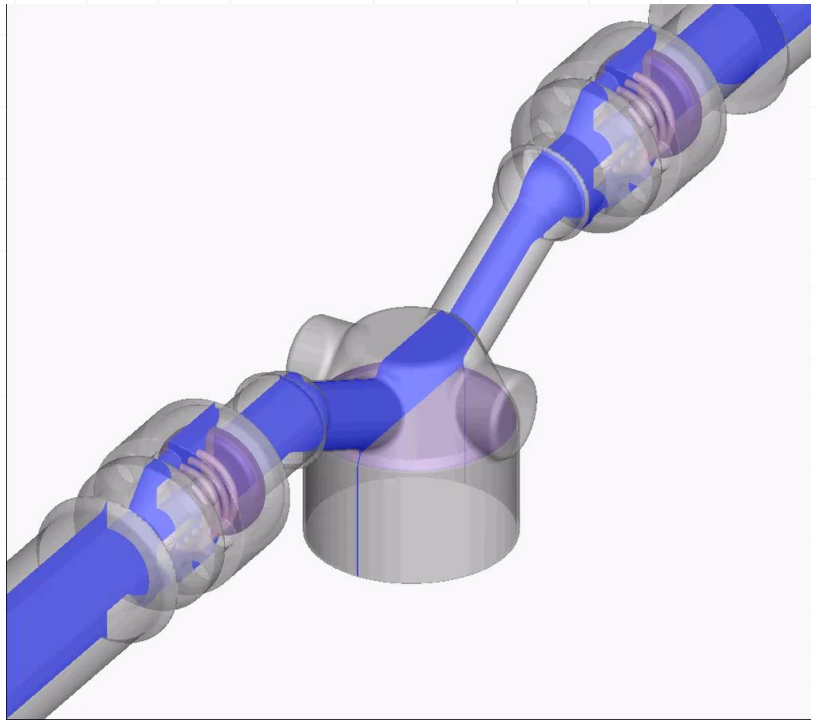


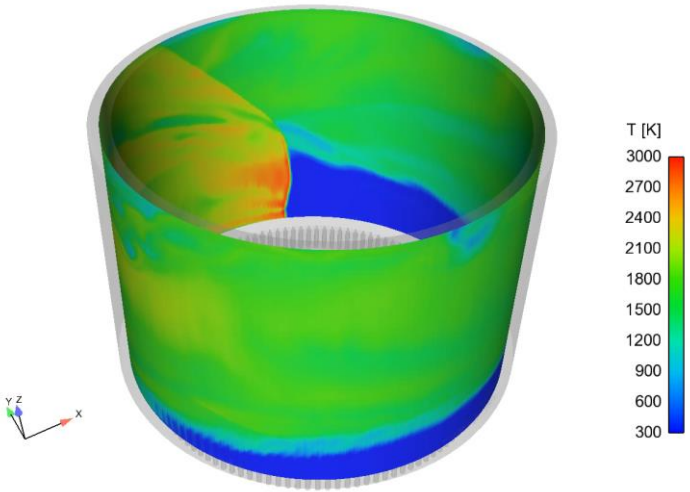
CONVERGE CFD SOFTWARE

Introduction & Outline

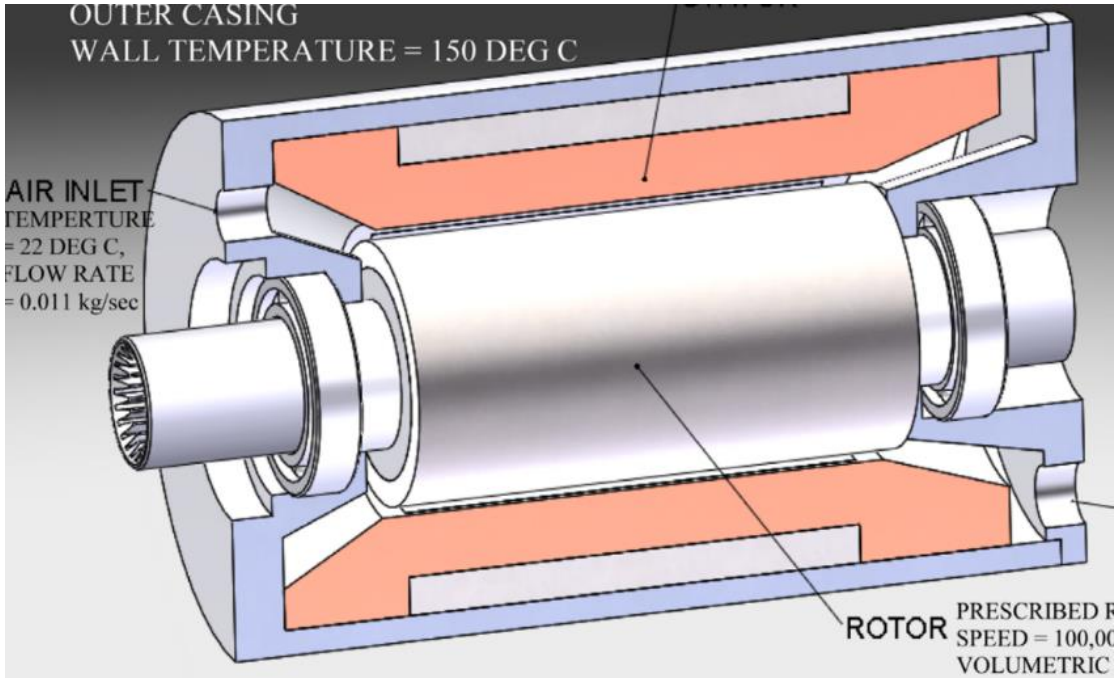
- The benefits of autonomous meshing and coupled flow and chemistry in CONVERGE are well recognized in the internal combustion engine community (内燃机：自动生成网格，流体和化学反应的耦合）
- This presentation focuses on the recently released functionalities in CONVERGE v3.0 that are beneficial in the following applications:
  - Electric motors (电机)
  - Biomedical flows （生物医学流动）
  - Burners （燃烧器）
  - Valves （阀门）
  - Gas turbines（燃汽轮机）
  - Engine aftertreatment（发动机后处理）
  - Pumps and compressors （泵和压缩机）

What's New in CONVERGE v3.0?

- RAM requirements in line with HPC hardware （节省内存）
  - RAM for 10M+ surface elements
  - RAM savings up to 2.5 times less than v2.4, allows 100's of millions of cells
- Cell based load balancing （基于网格的负载平衡）
  - Allows good load balance for all solution meshes, even with lots of embedding
- Better scalability （更好的可扩展性）
  - Scalability to 1k cells/core
- Pressure-based solver and SIMPLE solver for steady-state and aftertreatment
- Direct import of native CAD with Spatial （可直接读入CAD模型）
- Inlaid grids（镶嵌网格）
- Fixed flow（单向耦合流动）

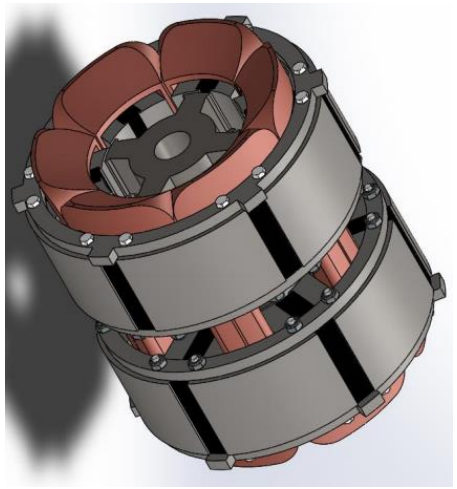


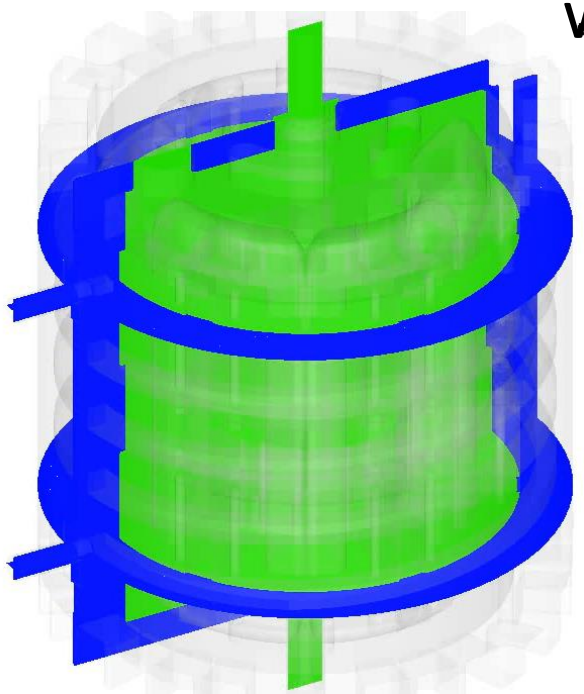
Electric Motors（电机）：



Electric Motor Cooling Simulation Needs

- Rotor-stator gap is often difficult to mesh with other tools
- Thermal simulations are not accurate, particularly in cases with oil cooling





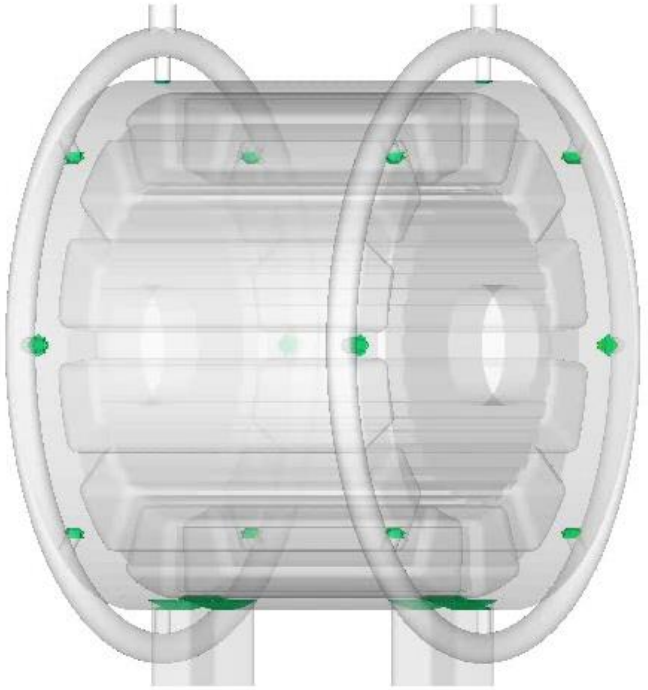
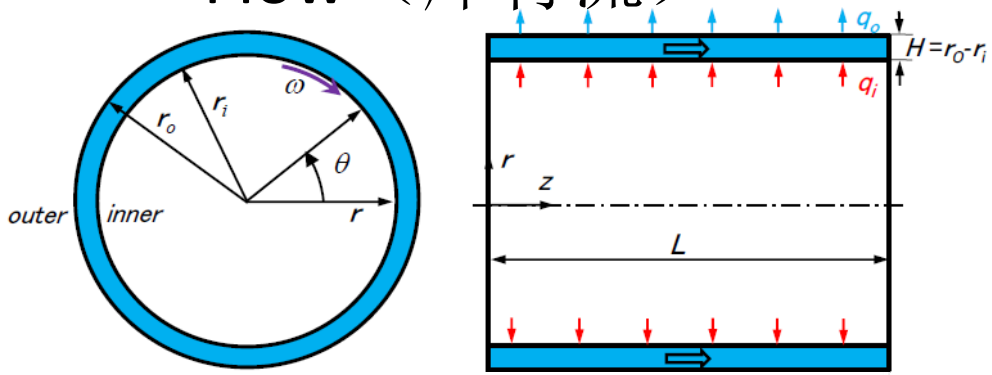


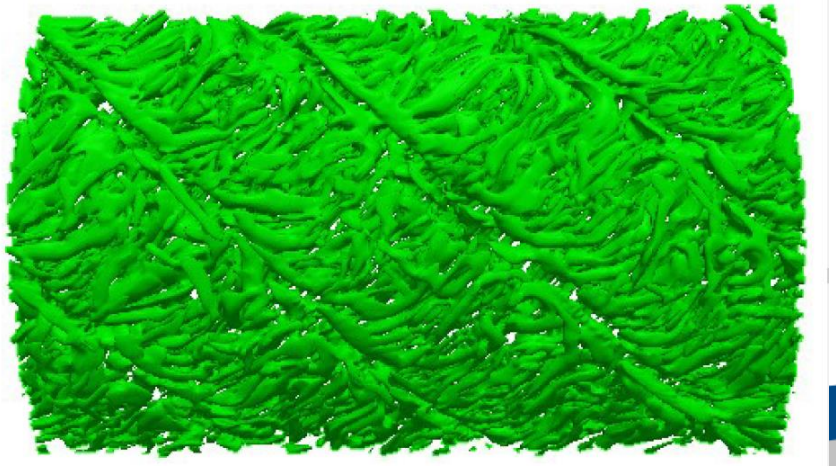
Table-3.2 Loss Distribution in Novel 6/4 FSPM Machine

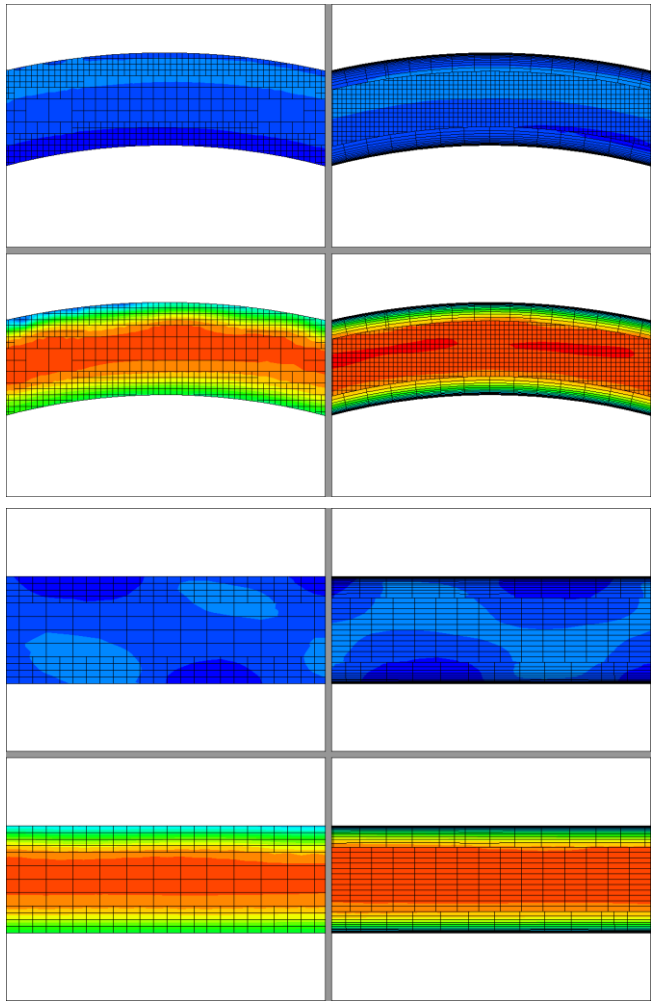
Copper loss (winding) [W]	126
Stator part 1 iron loss [W]	56
Stator part 2 iron loss [W]	112
Rotor iron loss [W]	84
Magnet eddy current loss [W]	129
Windage loss [W]	36
Total loss [W]	543

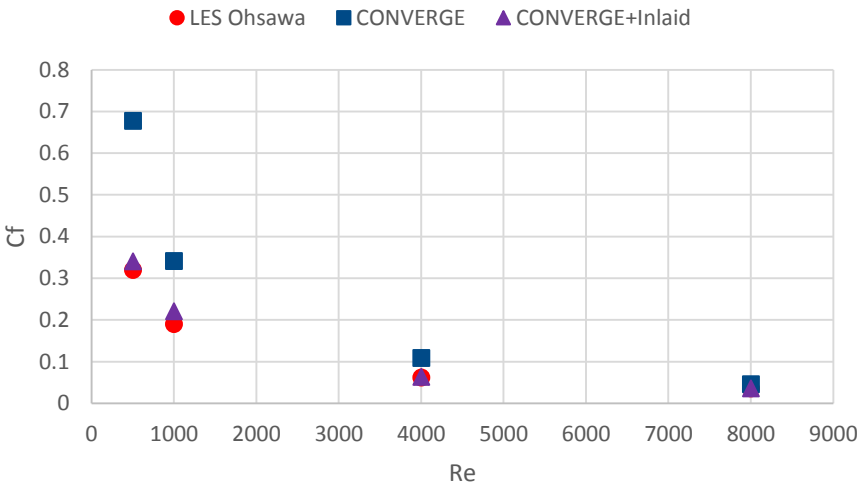
Inlaid Mesh For Simple Rotor-Stator Gap

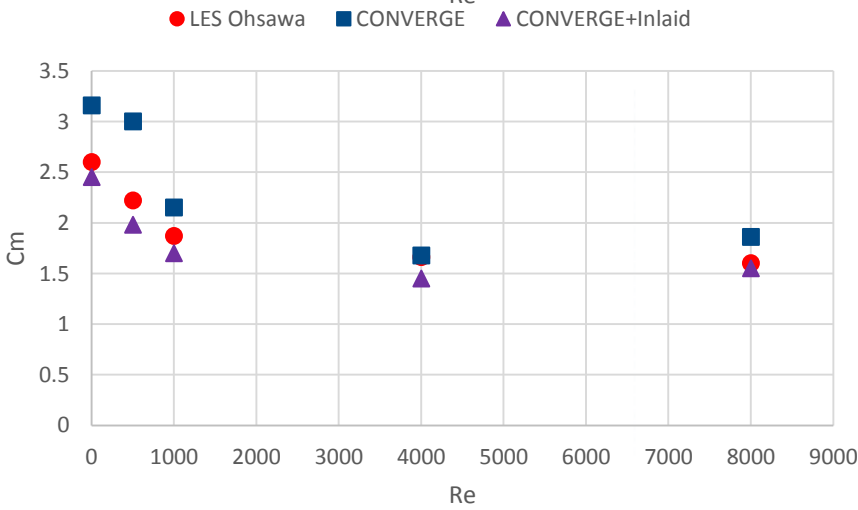
- Taylor-Couette-Poiseuille Flow（库特流）











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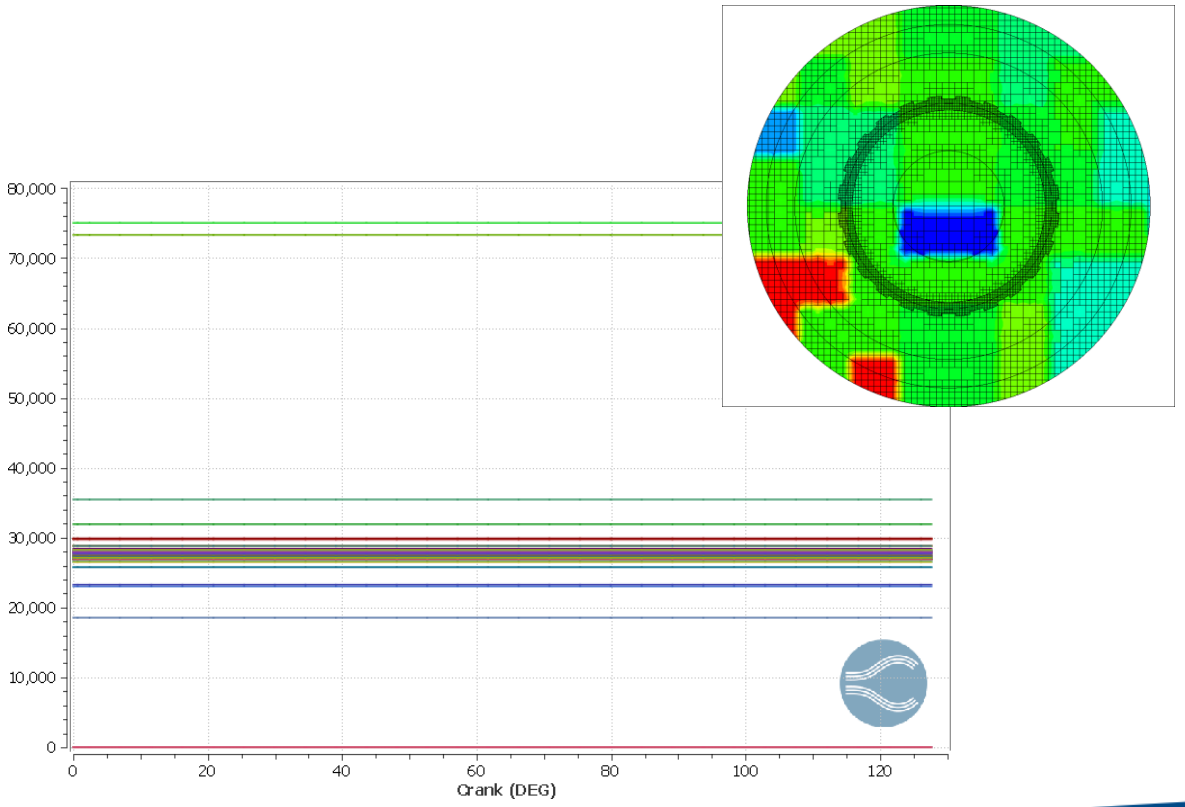
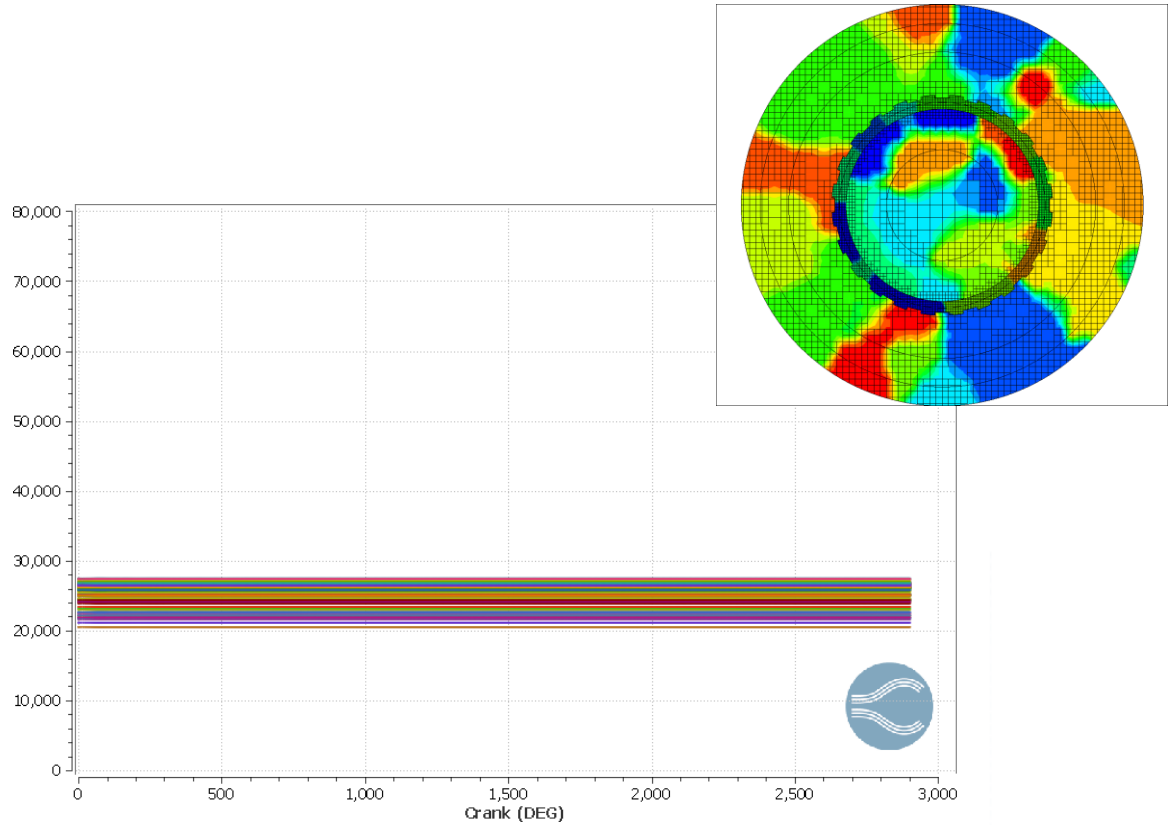
Motor Simulation Cell-Based Load Balancing

- 2M cells on 72 Cores

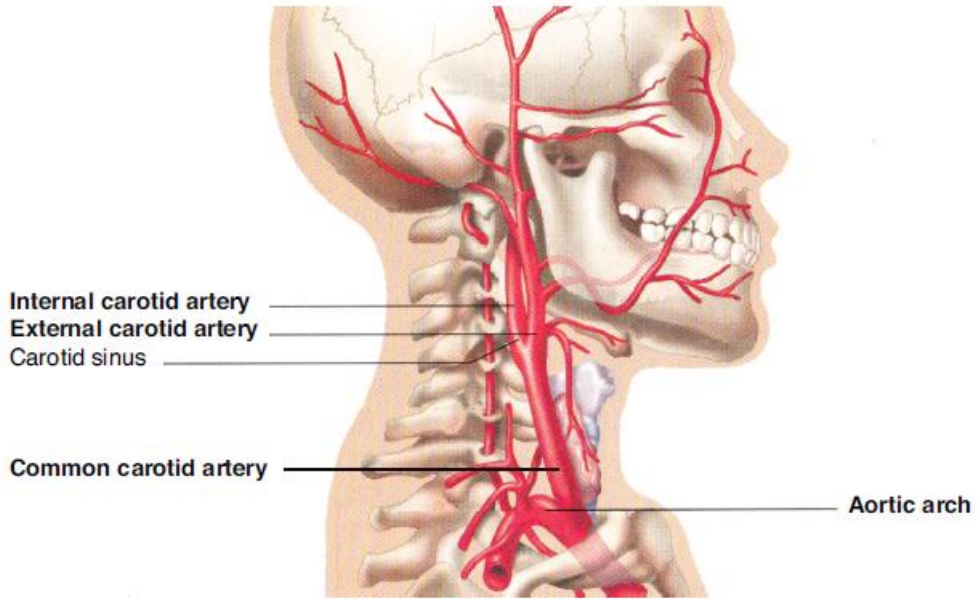


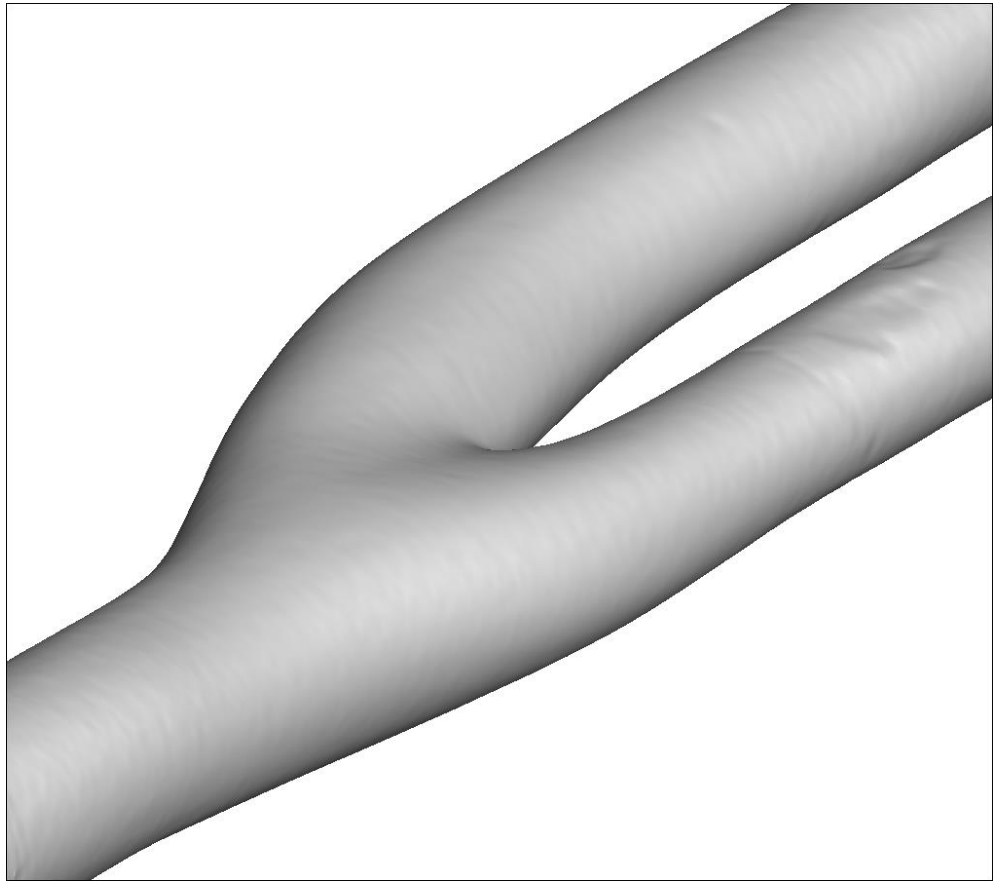
v2.4



v3.0

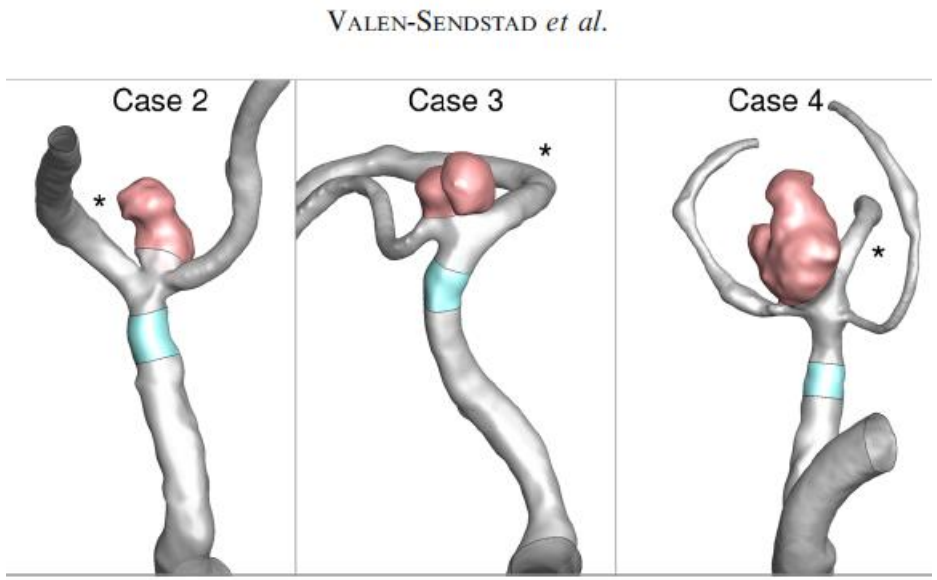
Biomedical（生物医学）：



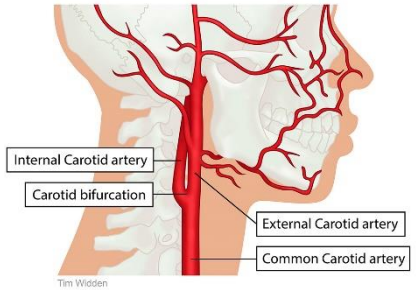


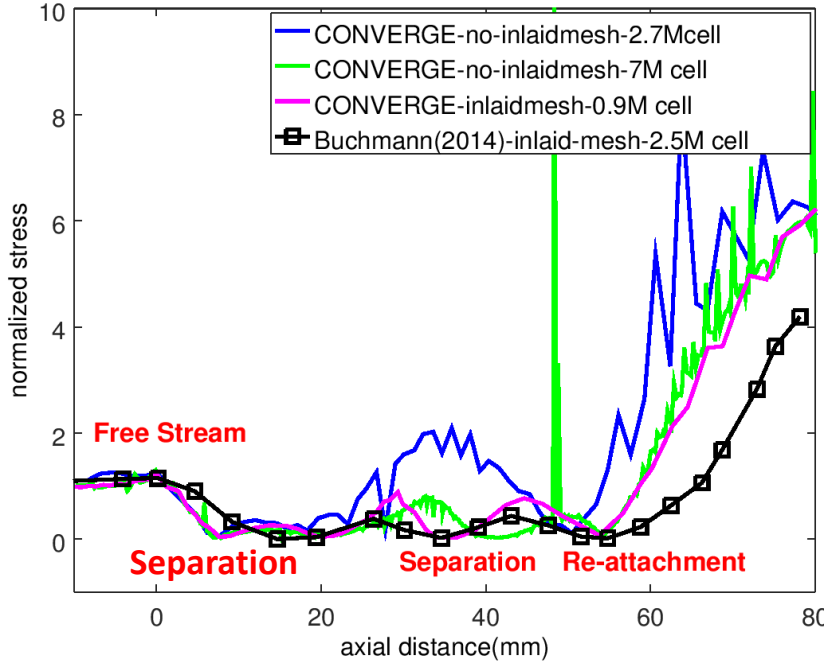
Biomedical Simulation Needs (血液流动)

- Geometries from magnetic resonance (MR) or computed tomography (CT) scans are challenging to mesh with high quality elements, even if geometry is assumed to be stationary
- Flow regimes range from unsteady laminar to transitional/weakly turbulent(层流或弱湍流）
- Accurate prediction of shear stress at vessel walls and within the vessel cross section are vital for blood damage (hemolysis), plaque growth (atherosclerosis) and aneurysm rupture predictions（溶血，动脉硬化，动脉瘤）

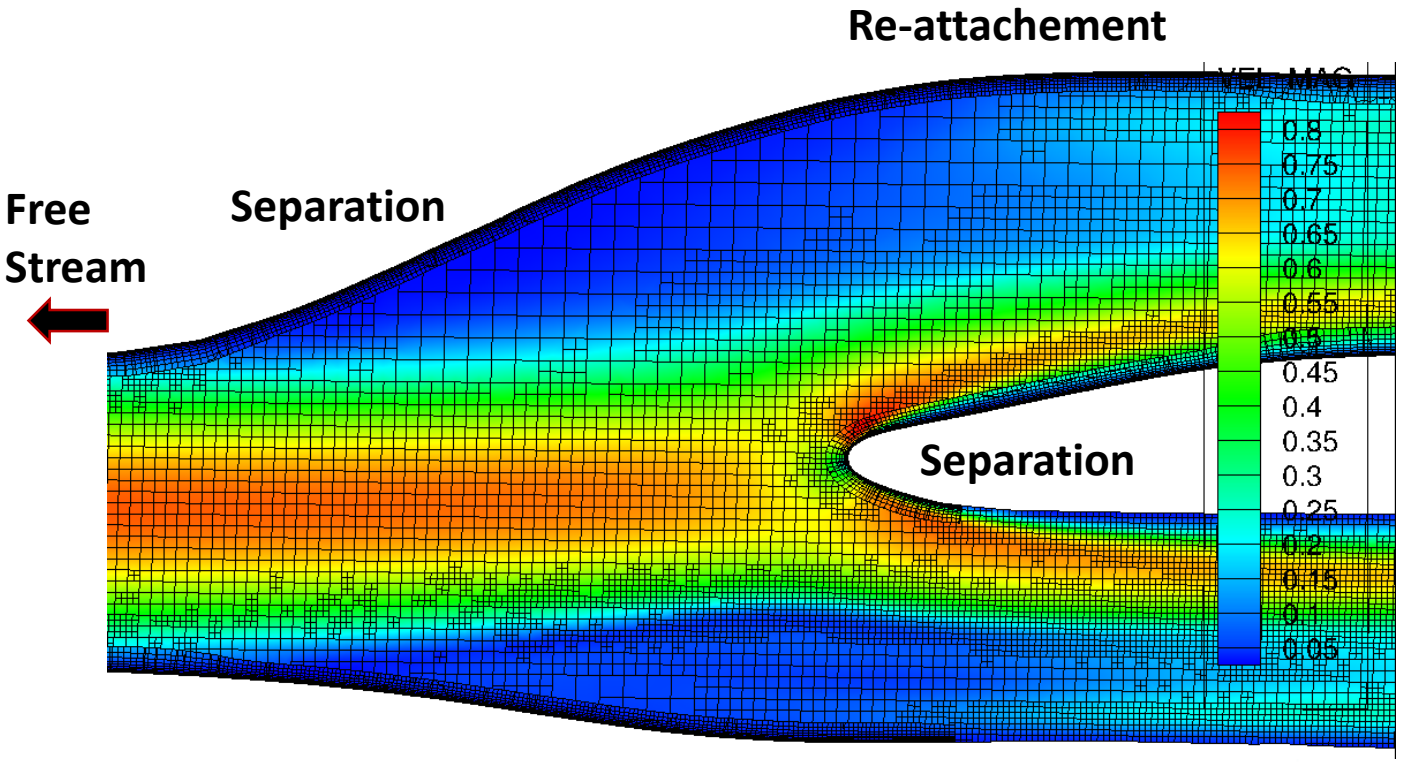


Vessel Shear Stress Distribution(壁面应力分布)





Shear Stress Prediction Along Internal Carotid Artery Wall



Velocity Contour and Flow Separation/Attachment

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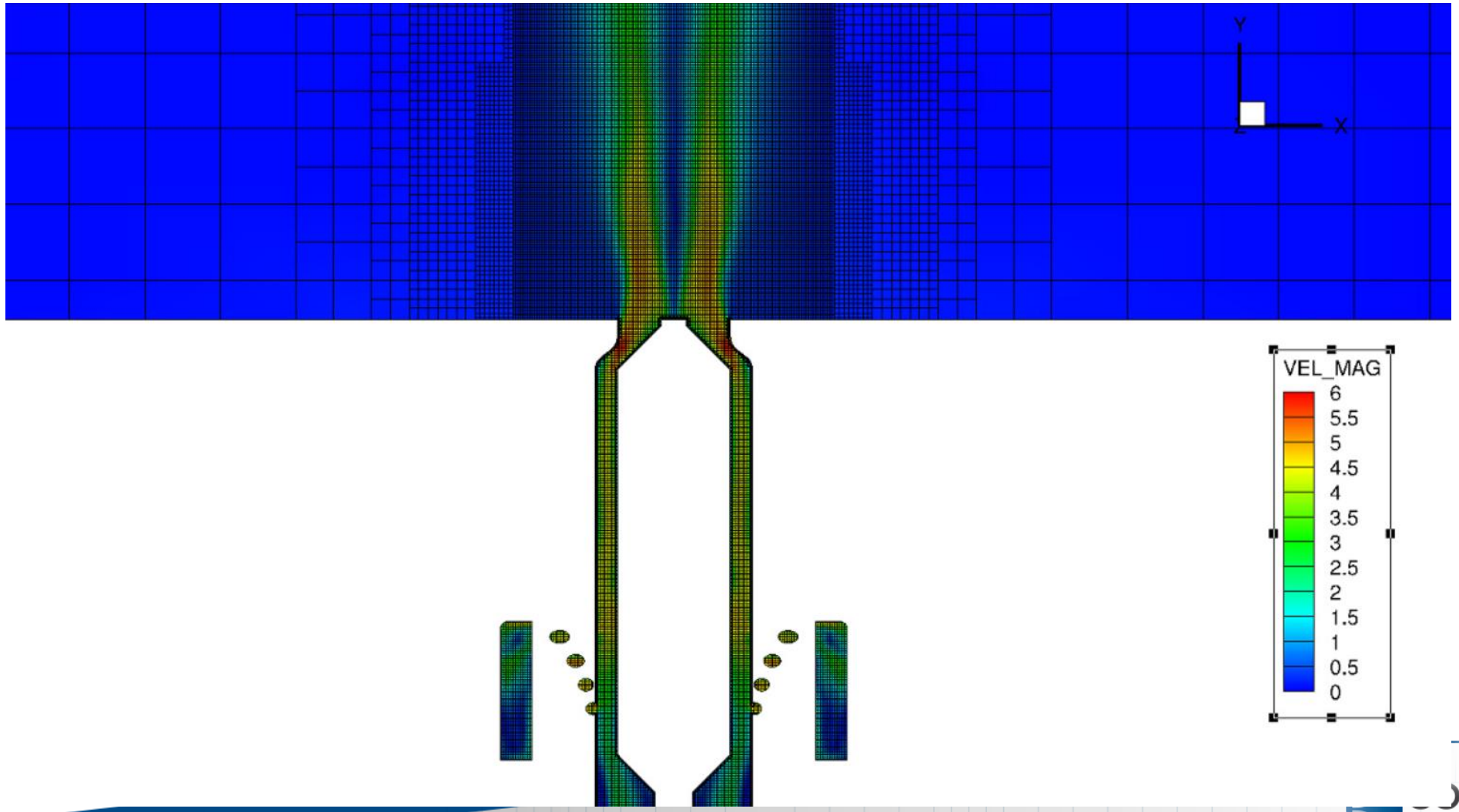
Burners（燃烧器）：



Burner Simulation (燃烧器模拟)

- Non-premixed burners include a wide range of important length scales that must be captured for accurate flame/emissions predictions

烟气

涡旋空气

天然气

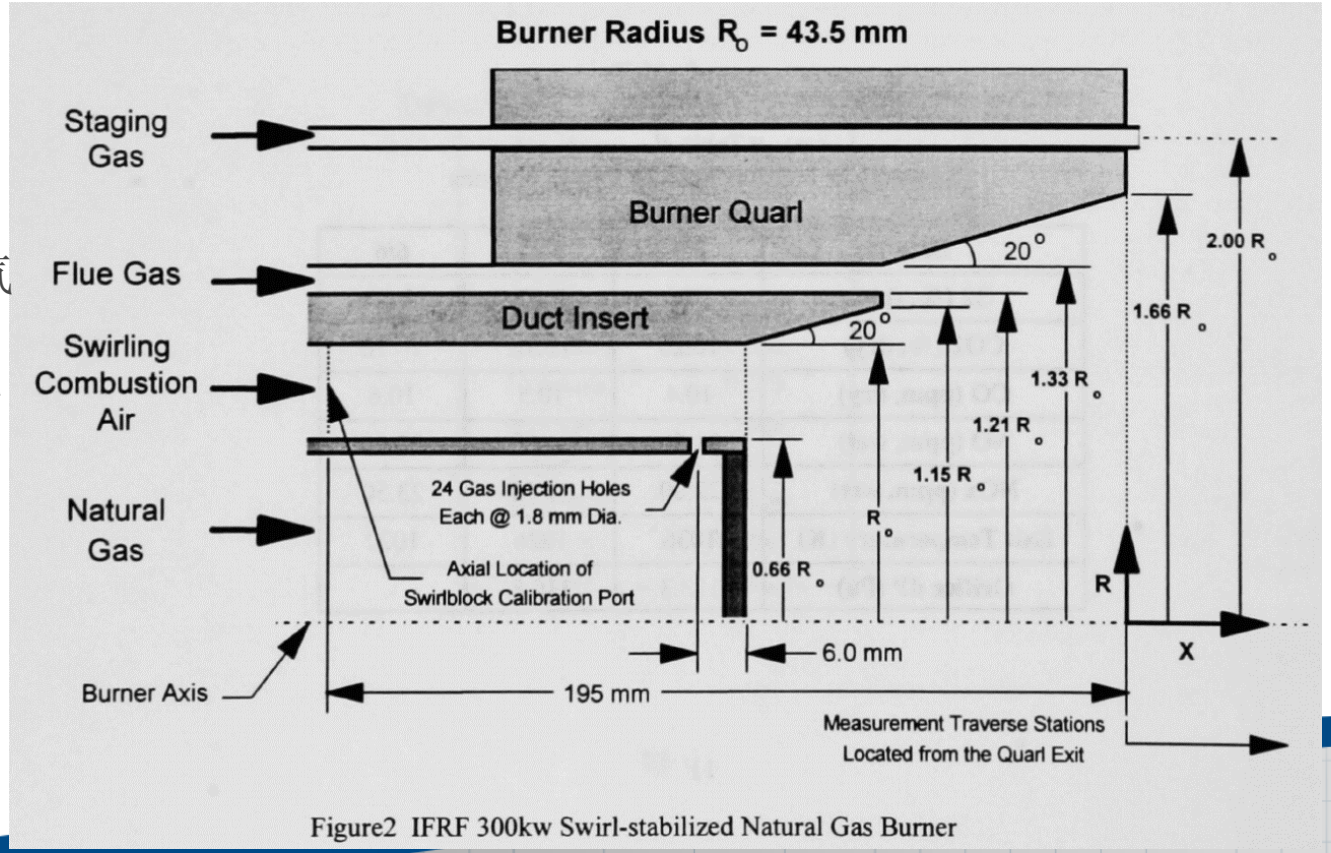
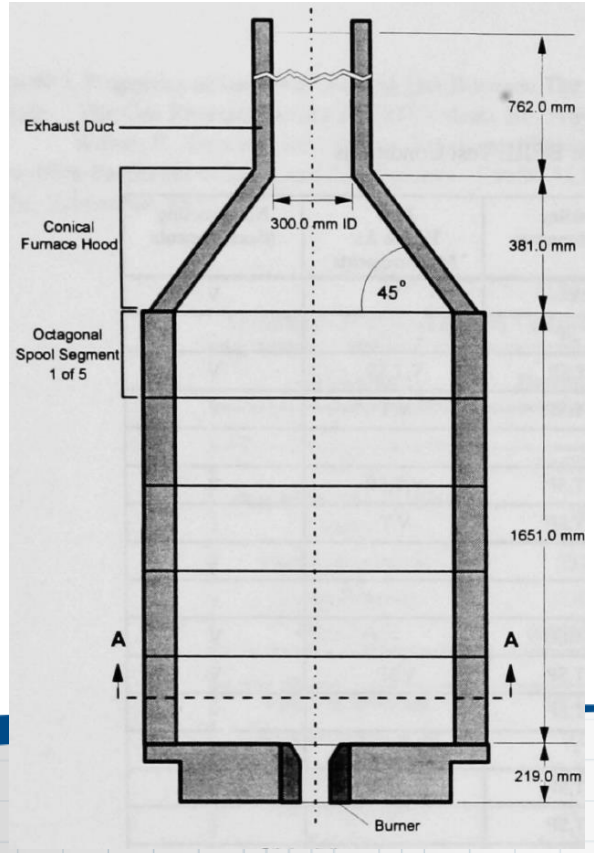
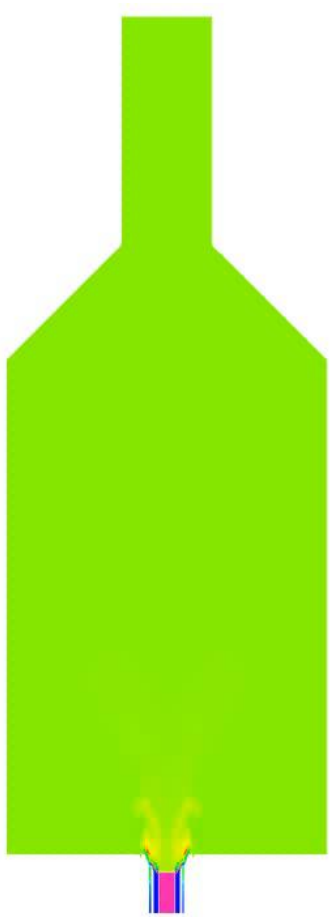
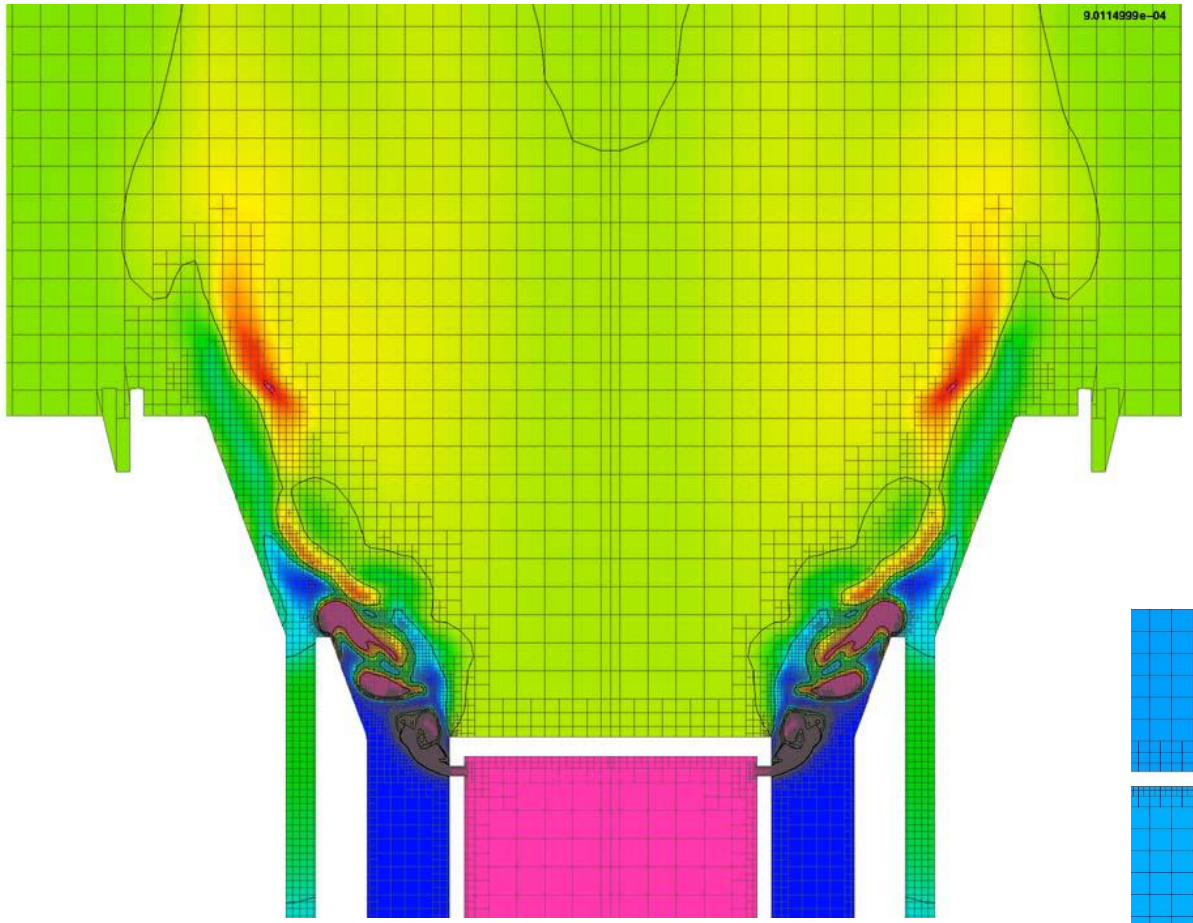


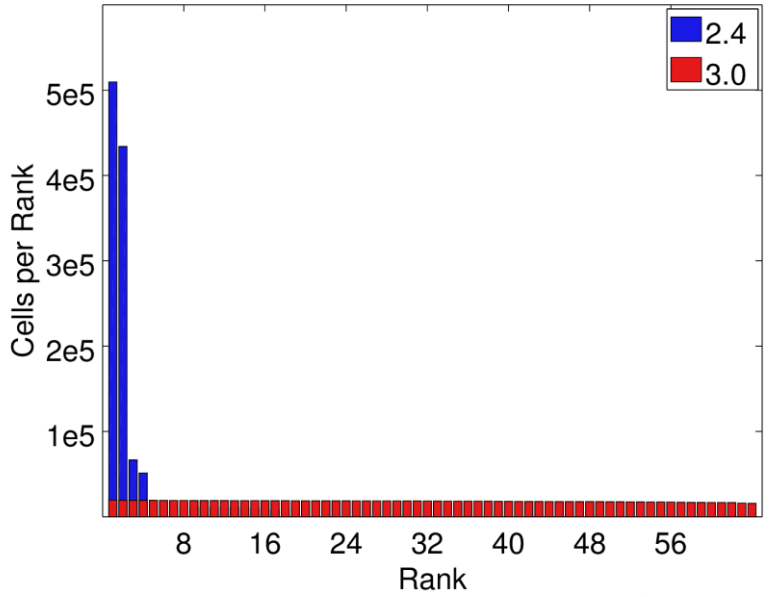
Figure2 IFRF 300kw Swirl-stabilized Natural Gas Burner

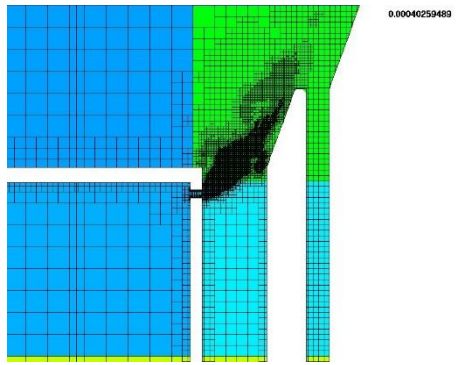


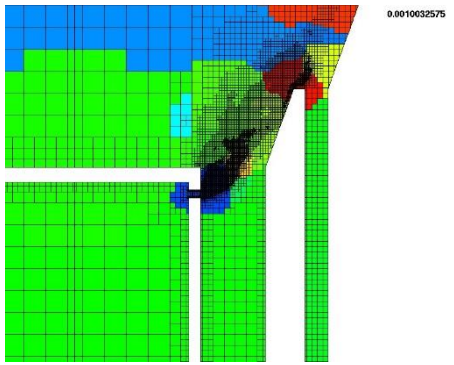
Burner Simulation Cell-Based Load Balancing



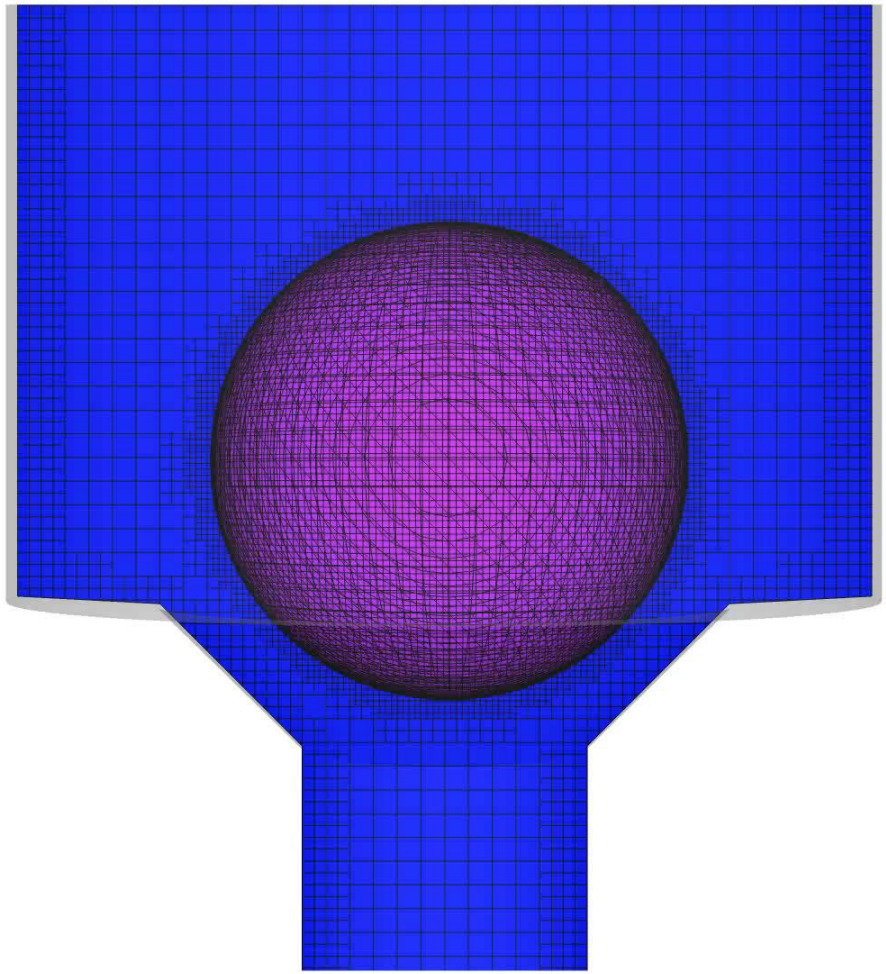


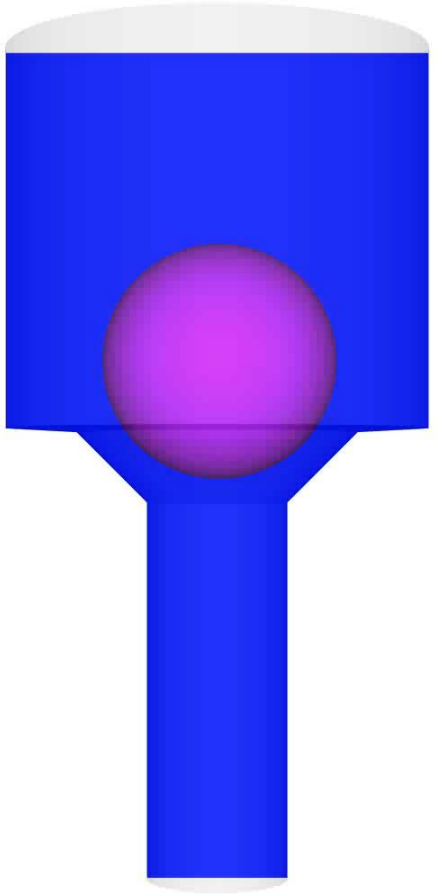






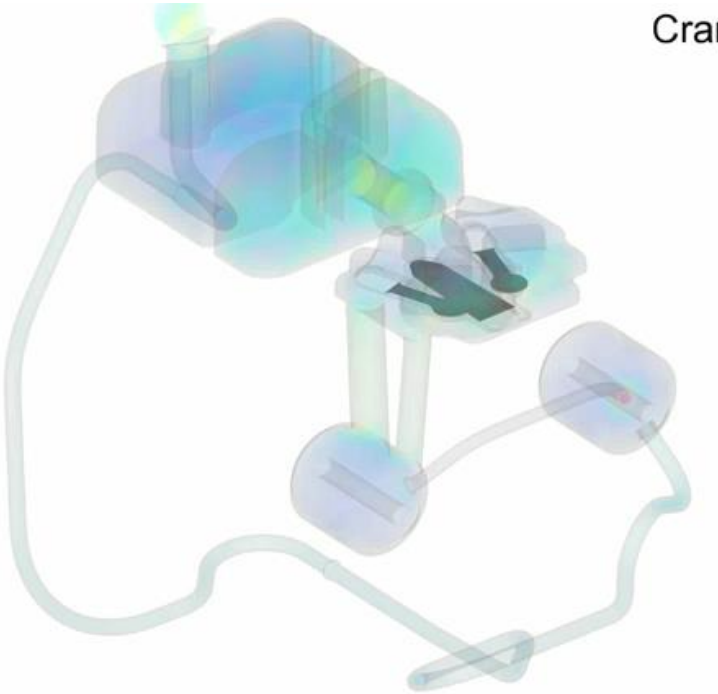
Valves（阀门）：

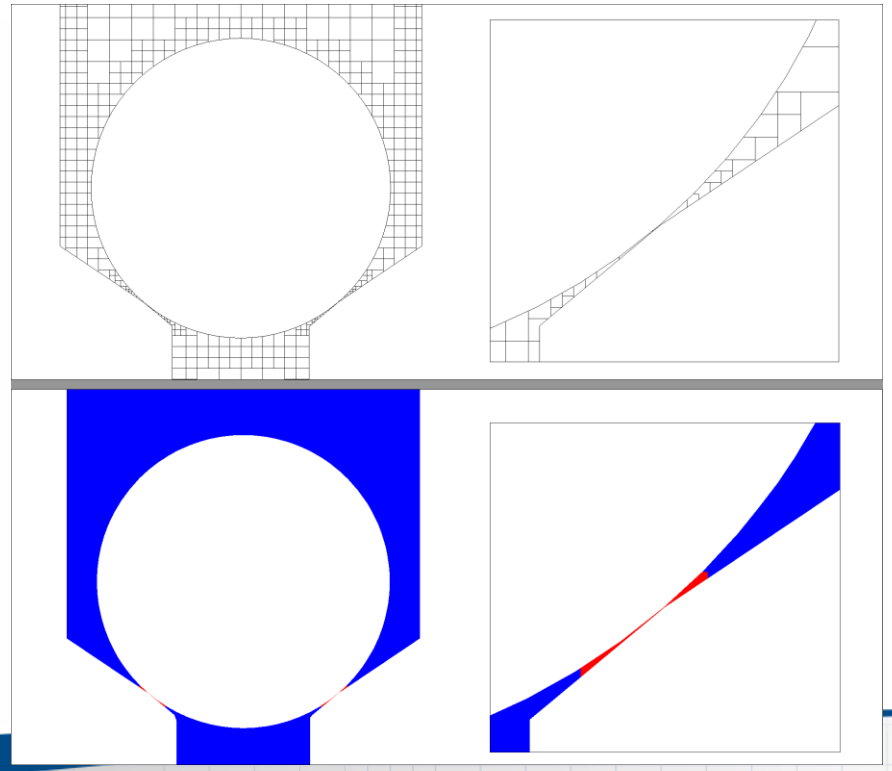




Valve Simulation Needs

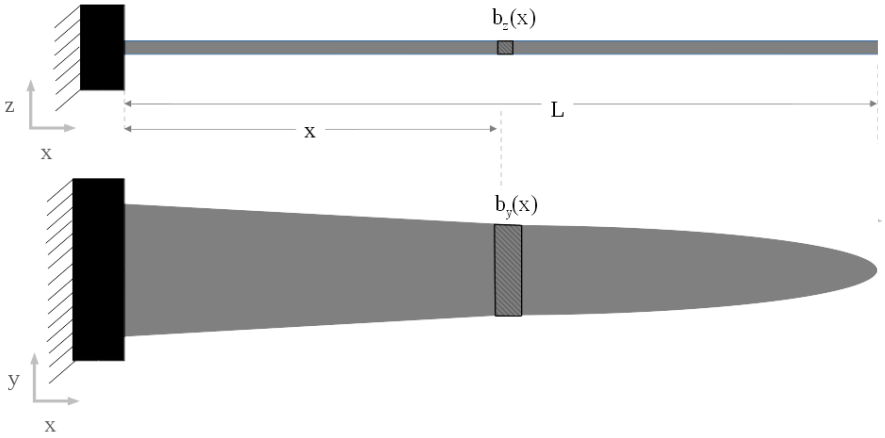
- 准确的阀性能预测需要复杂的气固耦合模型和好的方法模拟阀门的间隙。

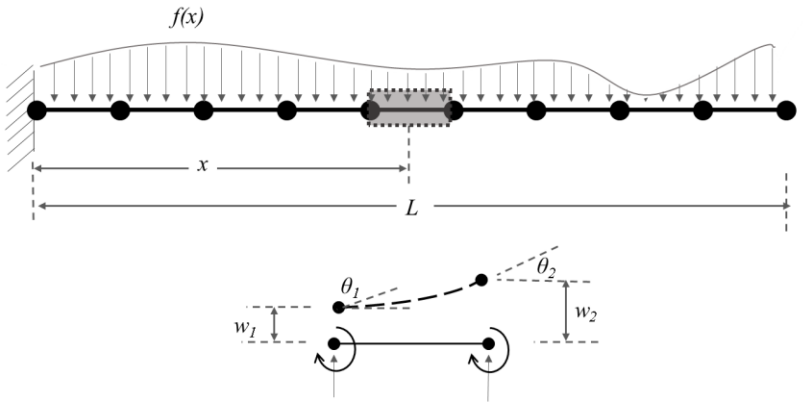


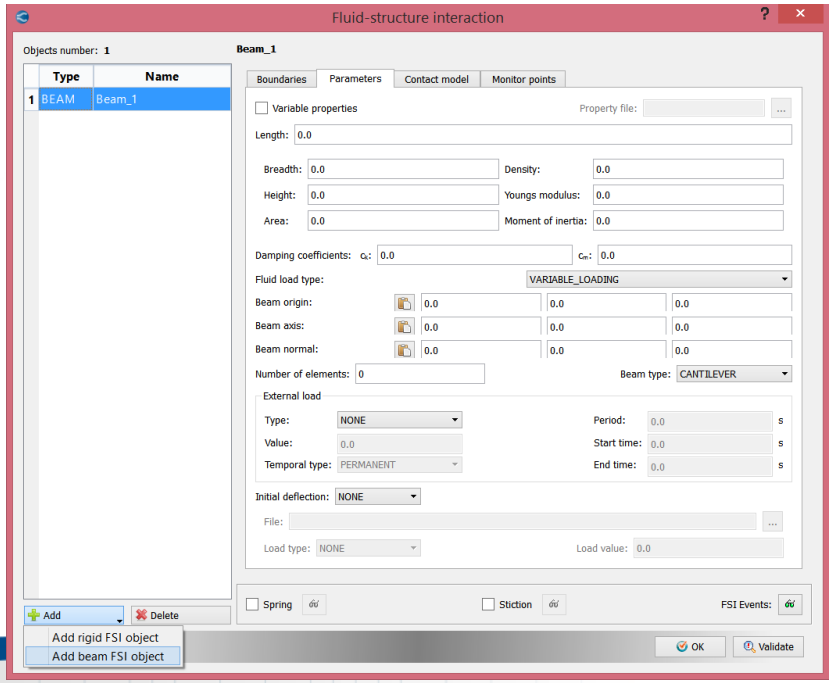


Beam Model for Reed Valves（用于簧片阀的平衡木模型）

- The beam deflection model treats the structure as a one-dimensional beam, discretized via the finite element method
  - Two nodes make up each finite element and each node has two degrees of freedom: displacement, *w,* and rotation, θ

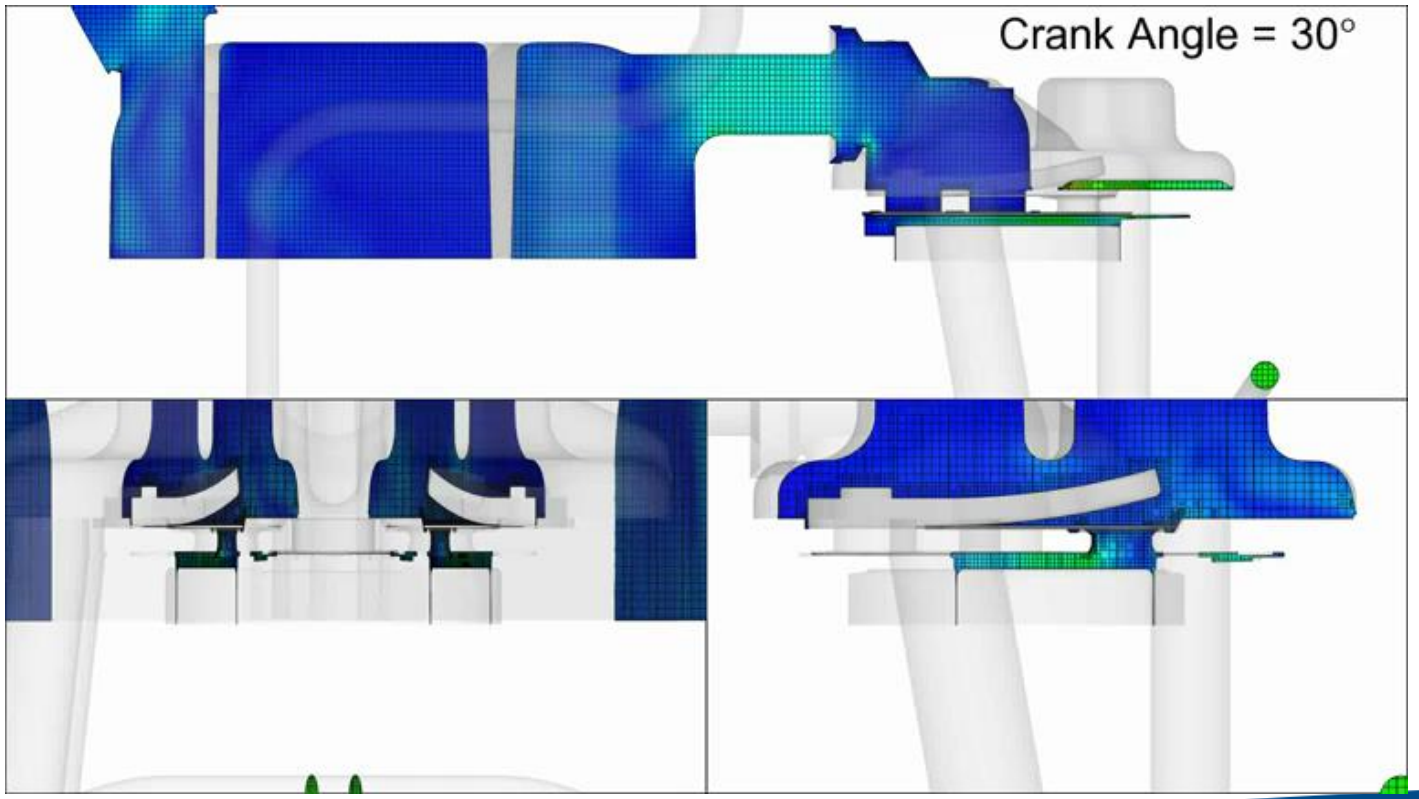


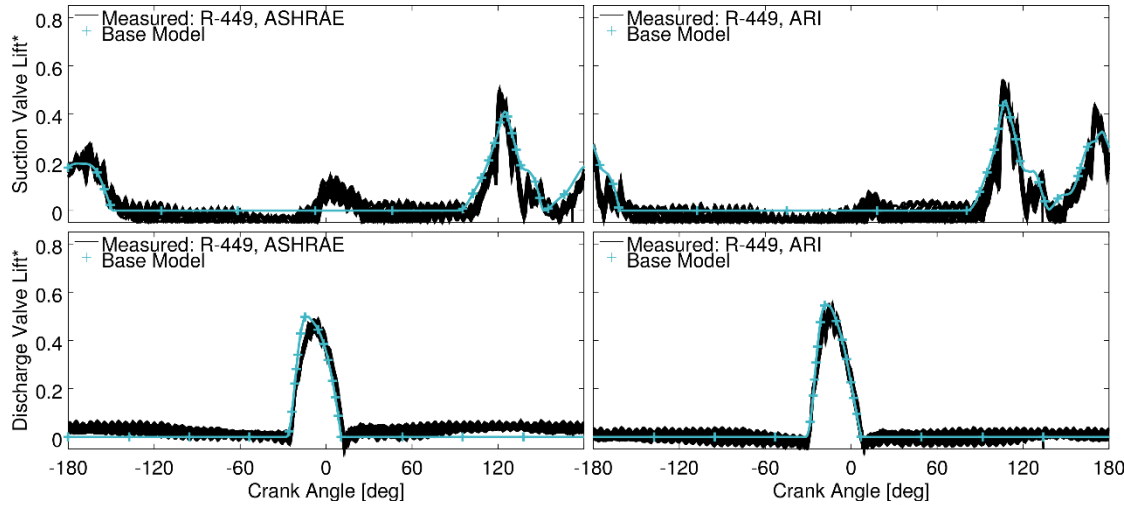




Reciprocating Compressor with Reed Valves （用于往复式压缩机的簧片阀）

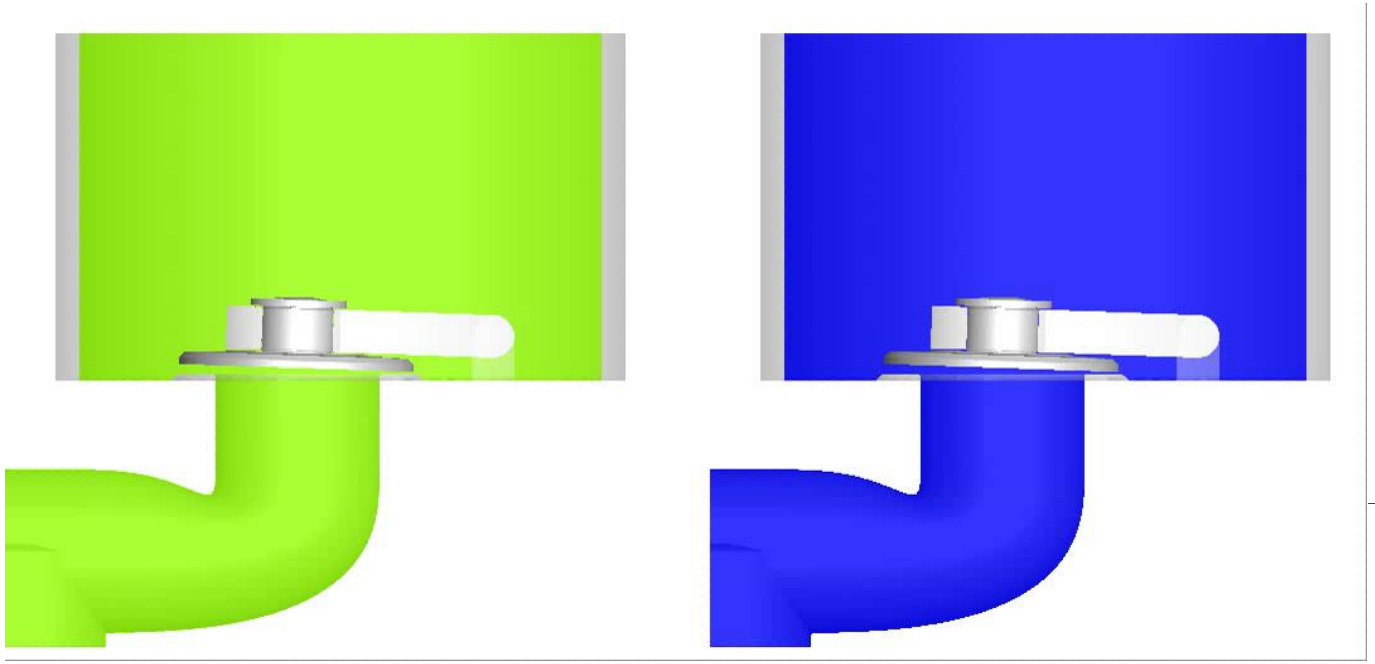
- “Modeling a Reciprocating Compressor Using a Two-Way Coupled Fluid and Solid Solver with Automatic Grid Generation and Adaptive Mesh Refinement”, 24th International Compressor Engineering Conference at Purdue, July 9-12, 2018

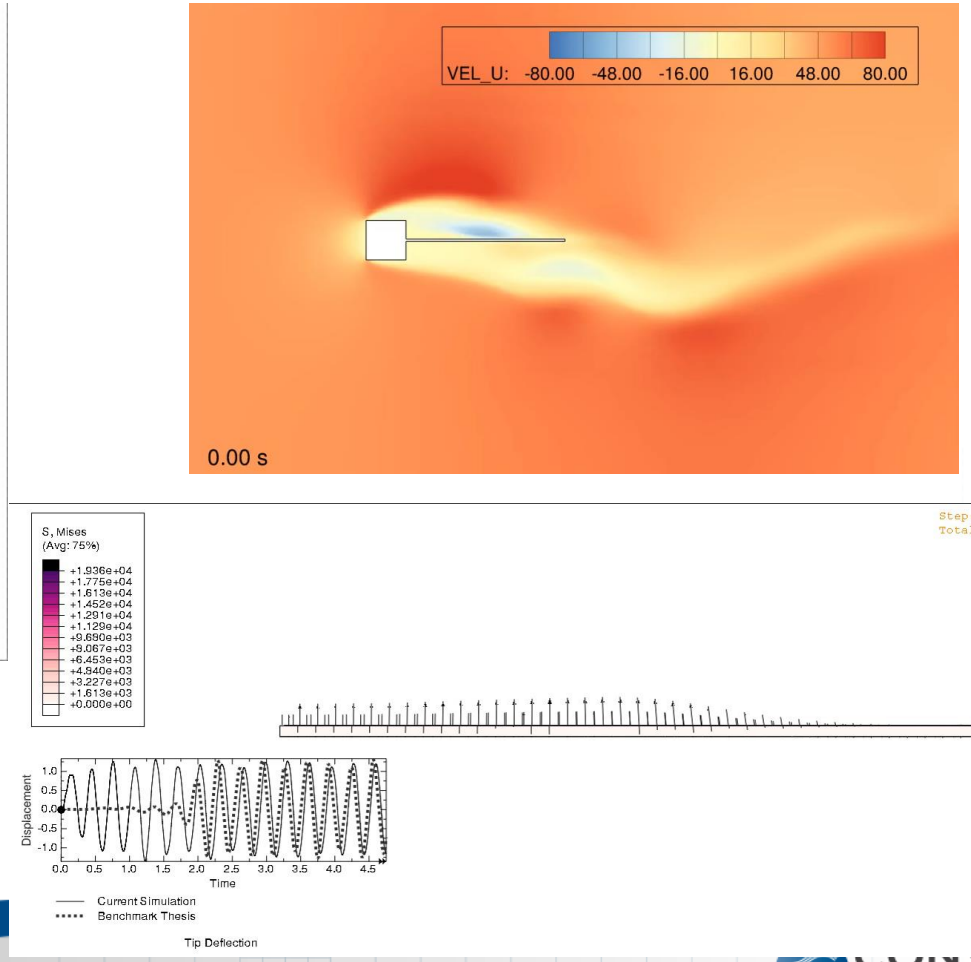




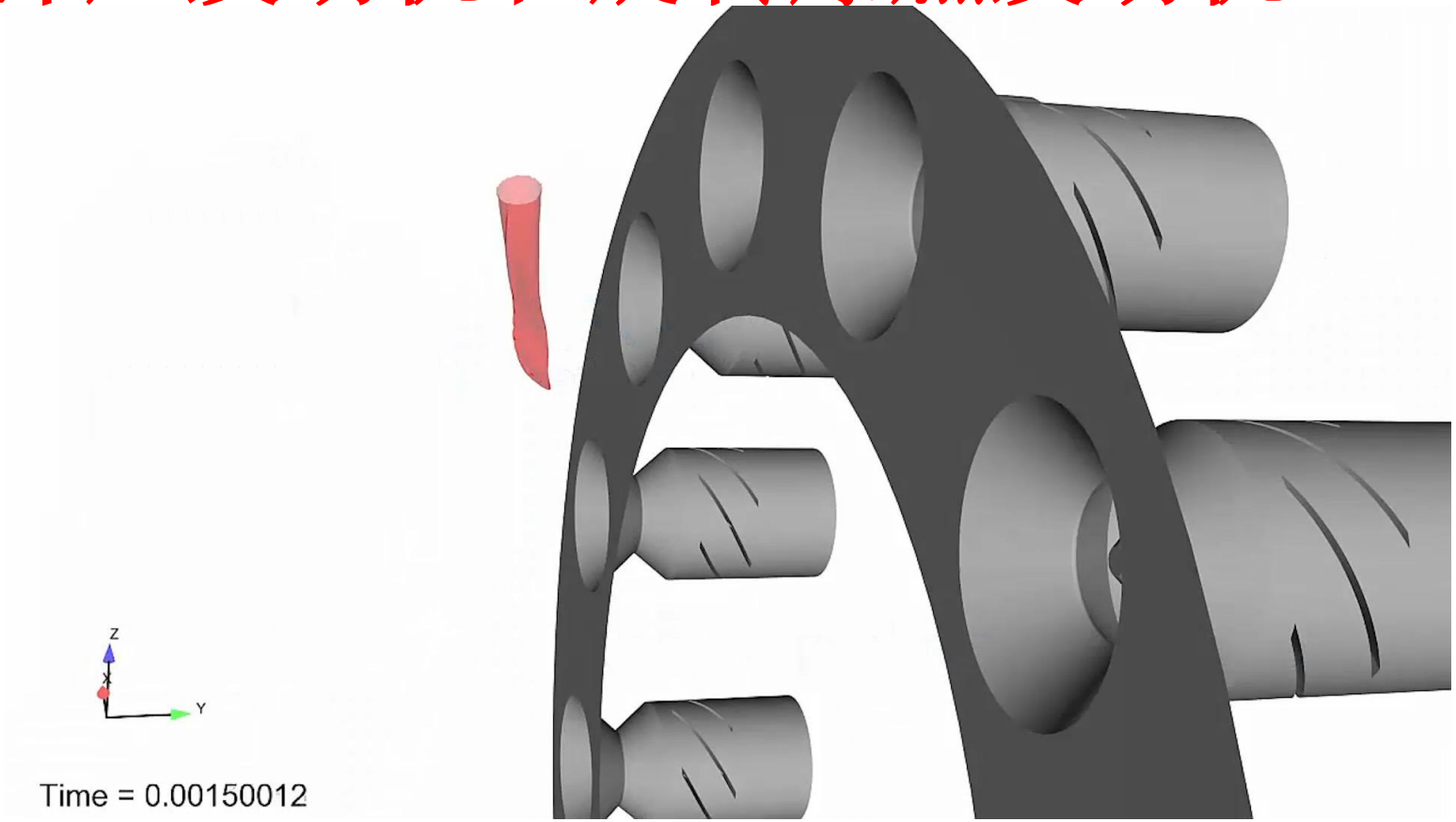
ABAQUS/CONVERGE FSI Coupling

- Allows 3-D deformation in the calculation (co-simulation)



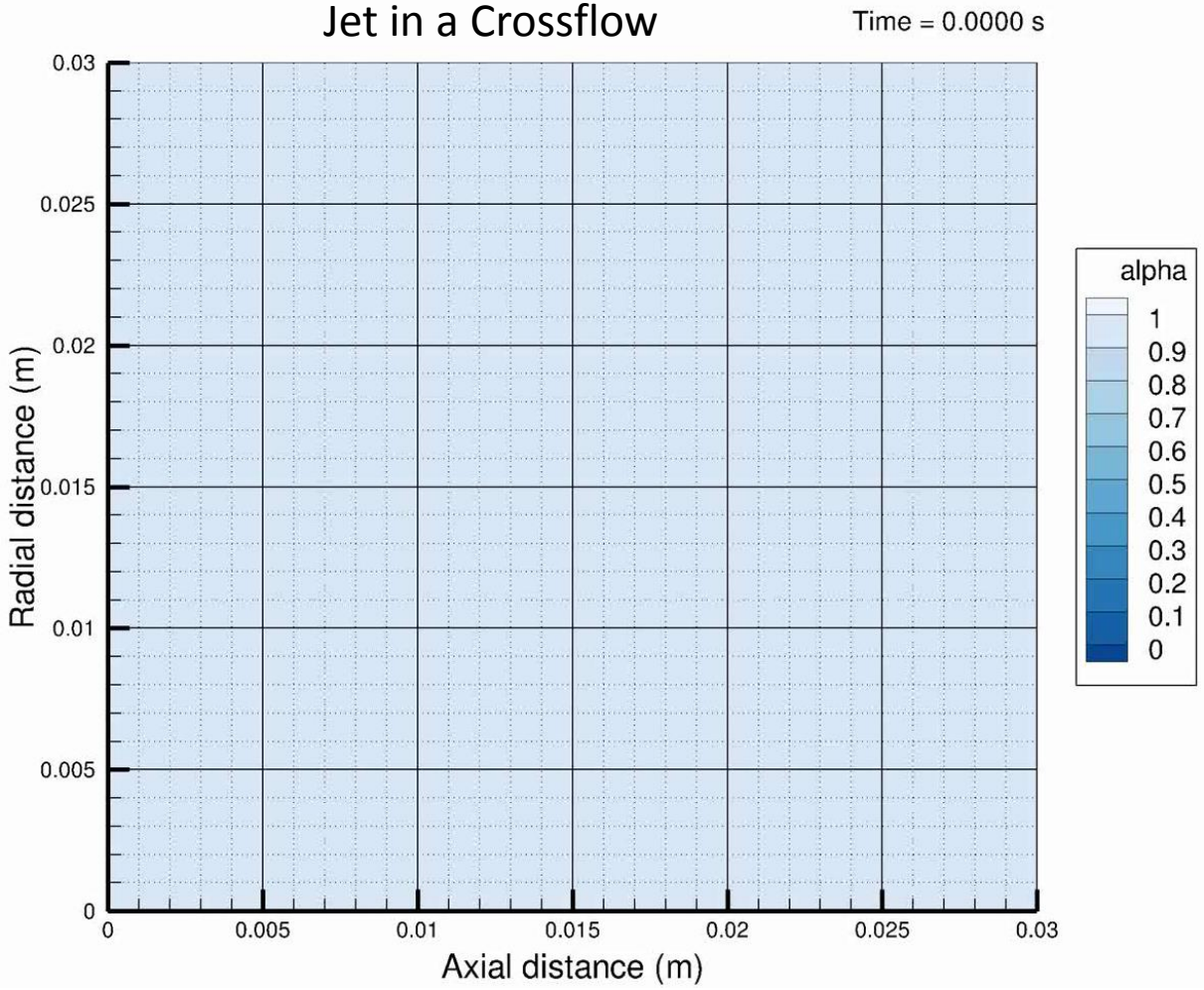


Gas Turbines, Scramjets, RDEs（燃气轮机，超燃冲压发动机和旋转爆燃发动机）：

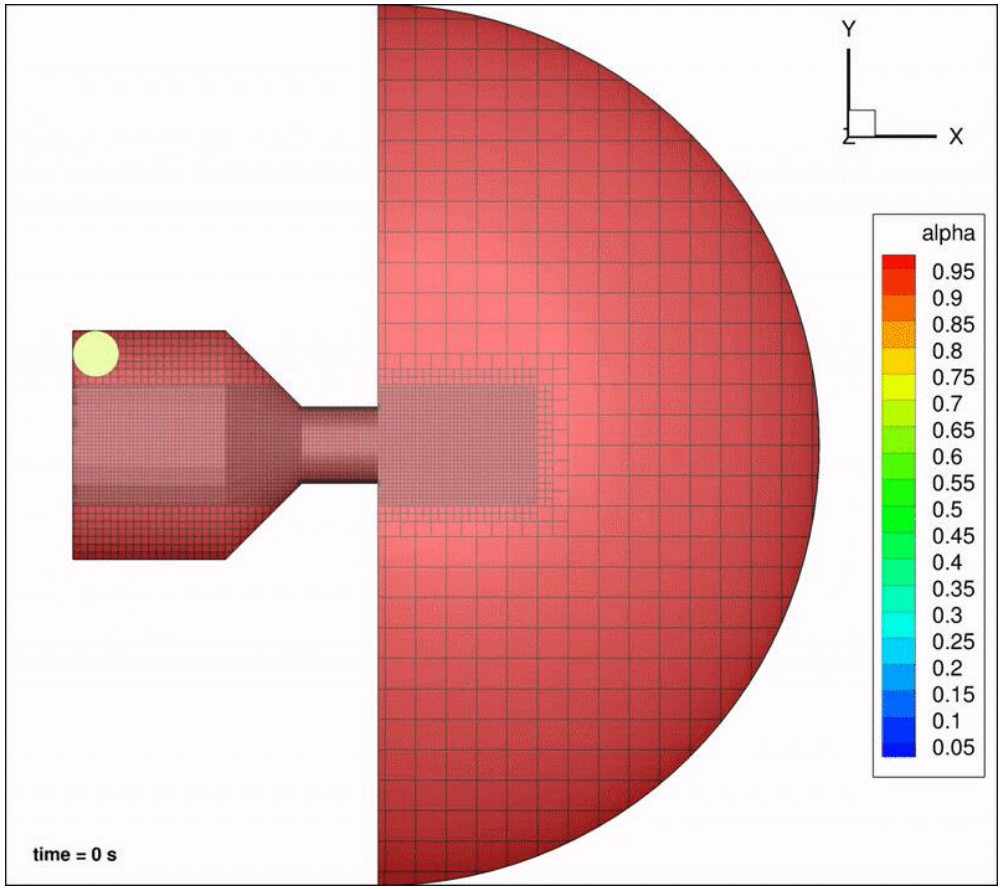


VOF Simulations

Jet in a Crossflow

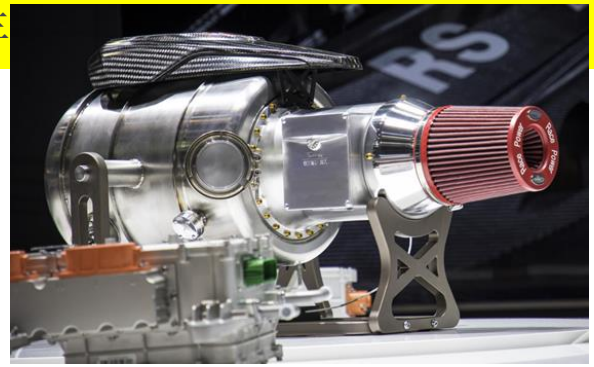


Pressure-Swirl Atomizer（压力旋流雾化器）



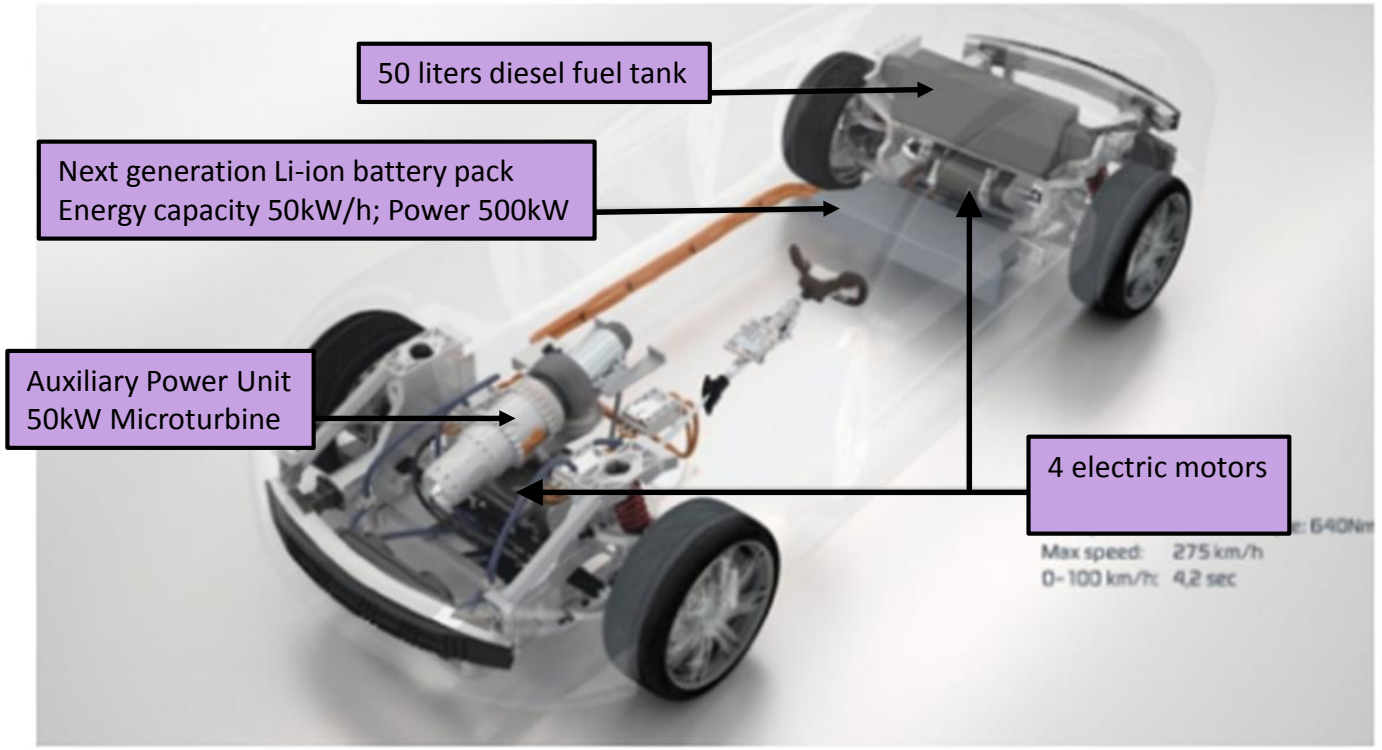
报告来源：2019年

Microturbine Range Extenders（微型透平续航器）



HK Motors (China)

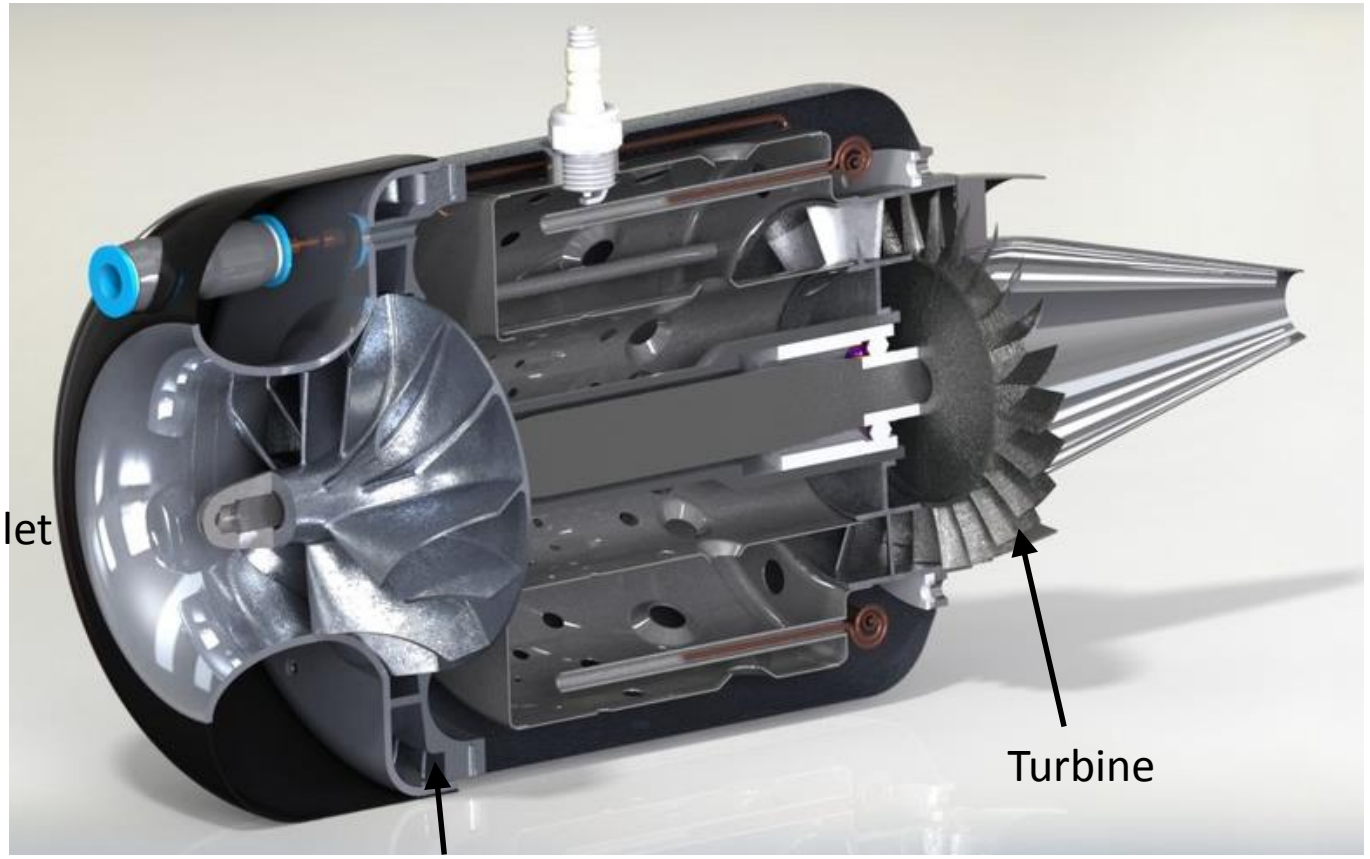
- Range extenders are combustion engines that generate electricity to charge batteries
- Advantages over piston engines
  - Higher power to weight ratio
  - Lower emissions (低排放）
    - No need for aftertreatment
  - Better fuel flexibility（燃料灵活）
    - Gasoline, diesel, H_2, LPG, etc.
  - Lower maintenance （低维护）
    - Fewer moving parts

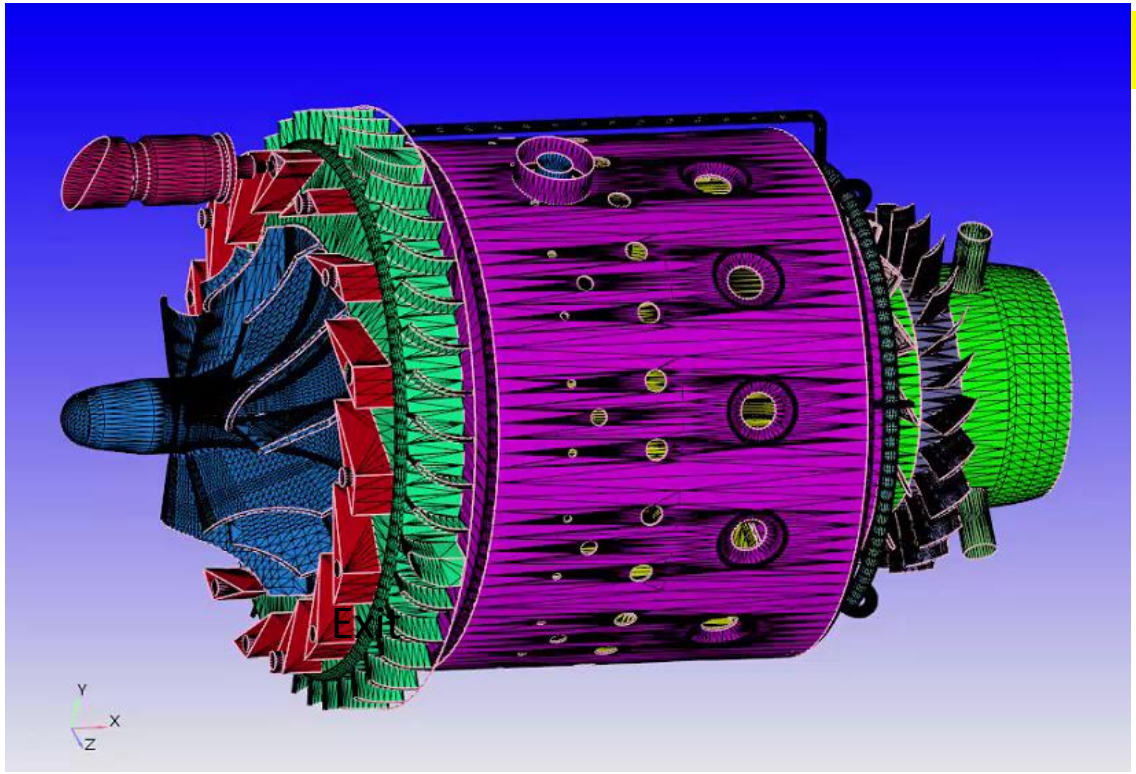


Posted on 20 March 2017 in Electric (Battery), Engines, Hybrids | Permalink | Comments (10)

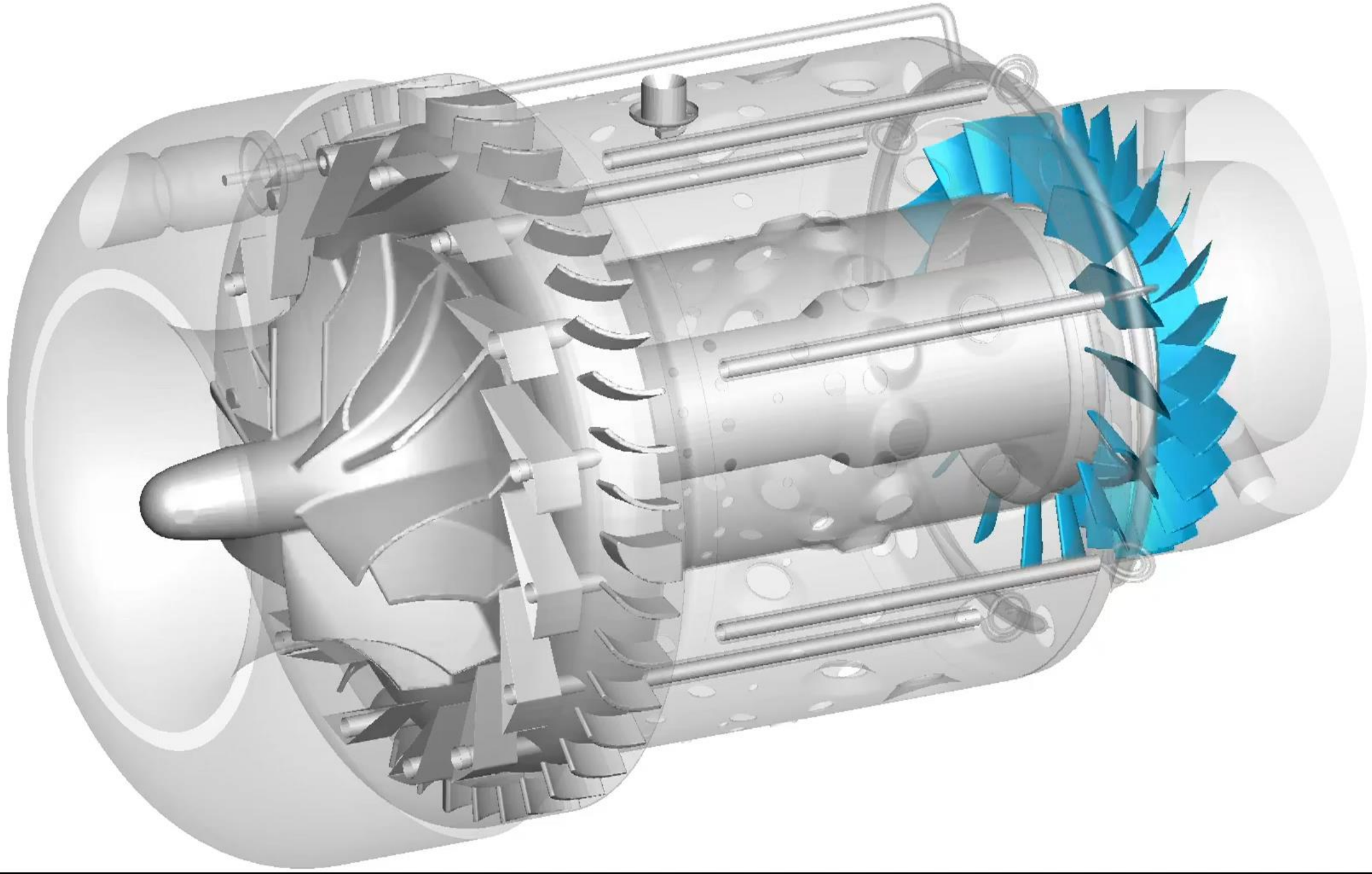
Microturbine model

- 4 bar pressure
- 800K preheat (recuperator)
- Gasoline fuel (Ø= 0.3)
- Reverse flow combustor
- Radial compressor
- Axial turbine





Adapted with permission by Saeid Mirshahidi
https://grabcad.com/library/kj-66-rc-turbojet-engine-1



Rotating Detonation Engine（旋转爆燃发动机）

- Rotating Detonation Engines (RDE)'s are …
  - Low cost, efficient, scalable, fuel flexible, reliable
- AFRL RDE Combustor Validation
  - Hydrogen/Air non-premixed
  - Super-sonic combustion wave

Proceedings of ASME Turbo Expo 2019: Turbomachinery Technical Conference and Exposition
GT2019
June 17-21, 2019, Phoenix, Arizona, USA

GT2019-91931

Argonne NATIONAL LABORATORY

MULTIDIMENSIONAL NUMERICAL SIMULATIONS OF REACTING FLOW IN A NON-PREMIXED ROTATING DETONATION ENGINE

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Gaurav Kumar
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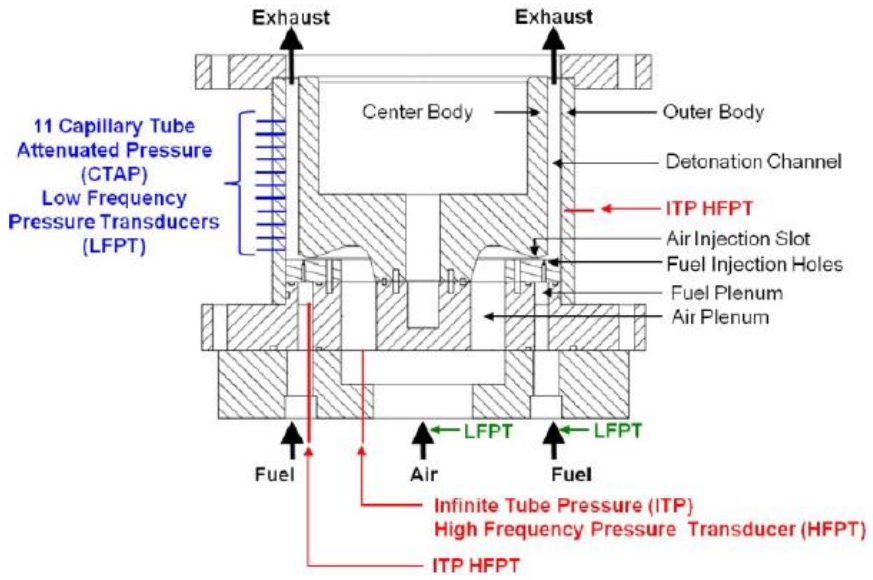

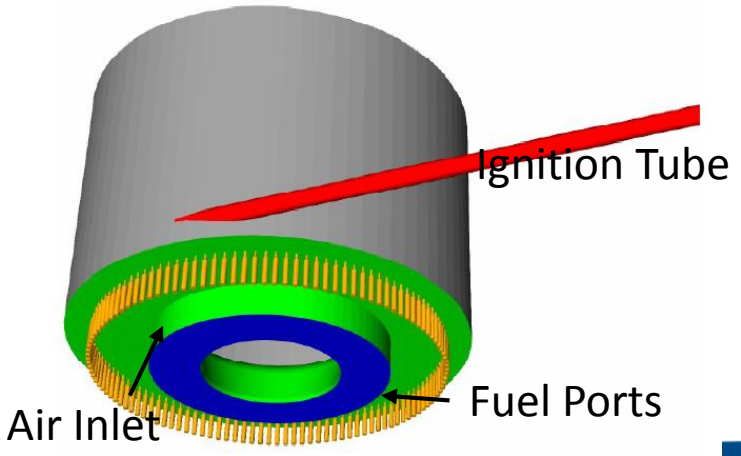

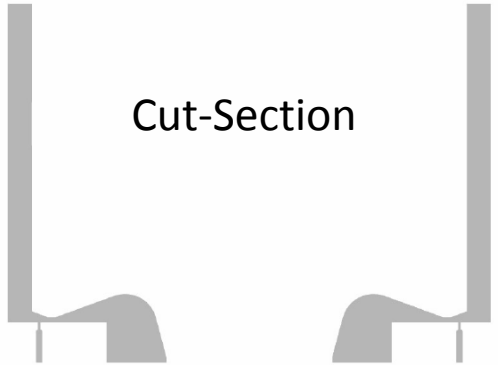

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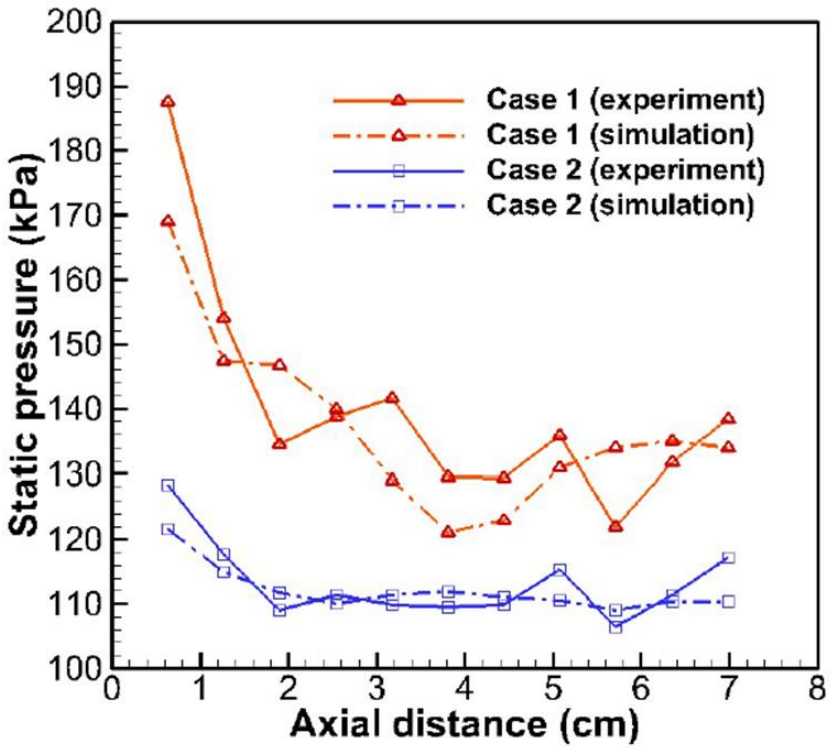
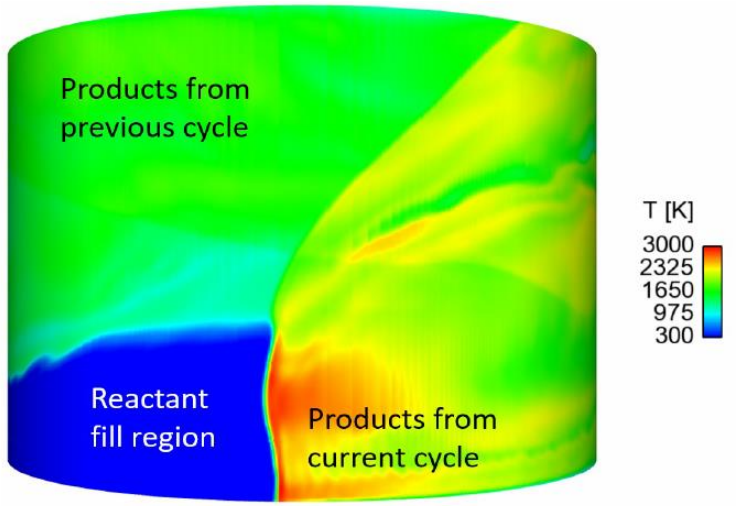
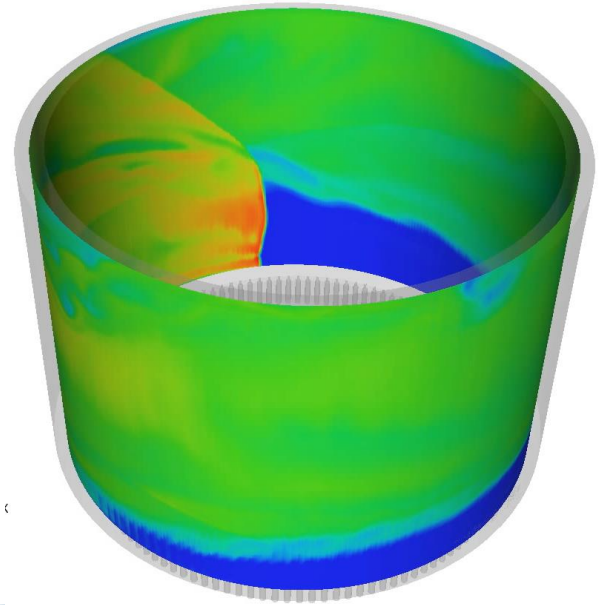
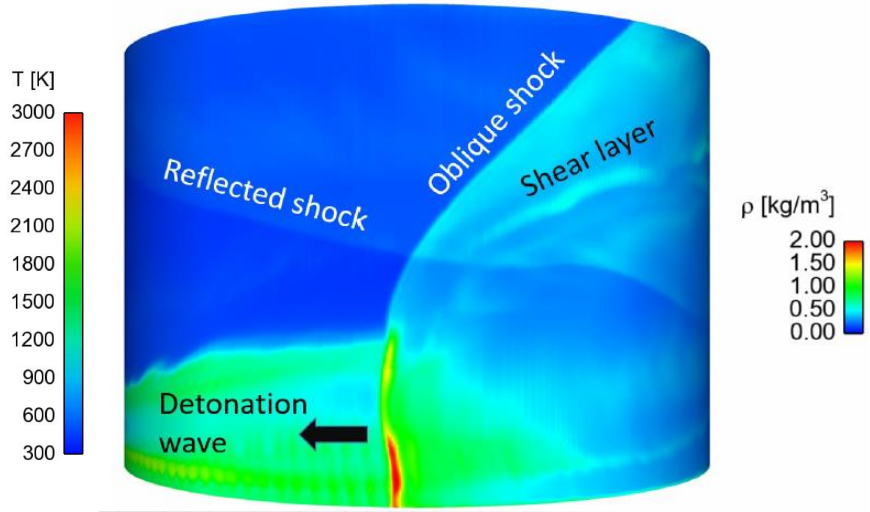
RDE Results and Next Steps



- Hydrocarbon fuels
- Investigate liquid/shock effects
- Mesh and solver effects







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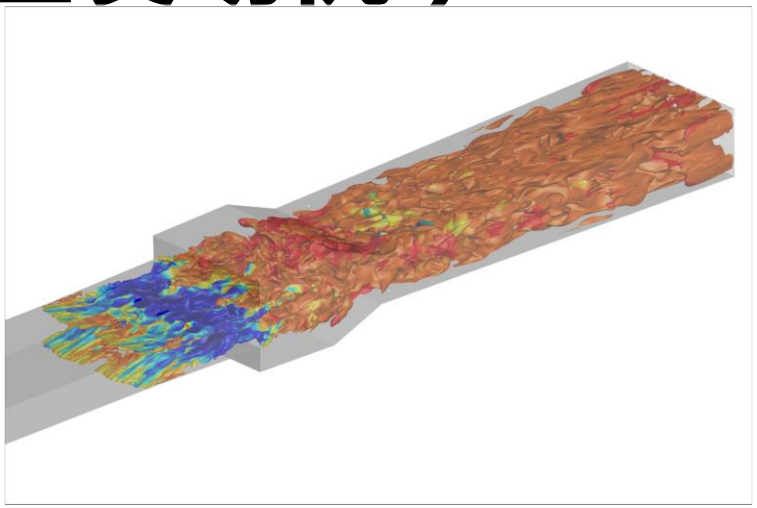
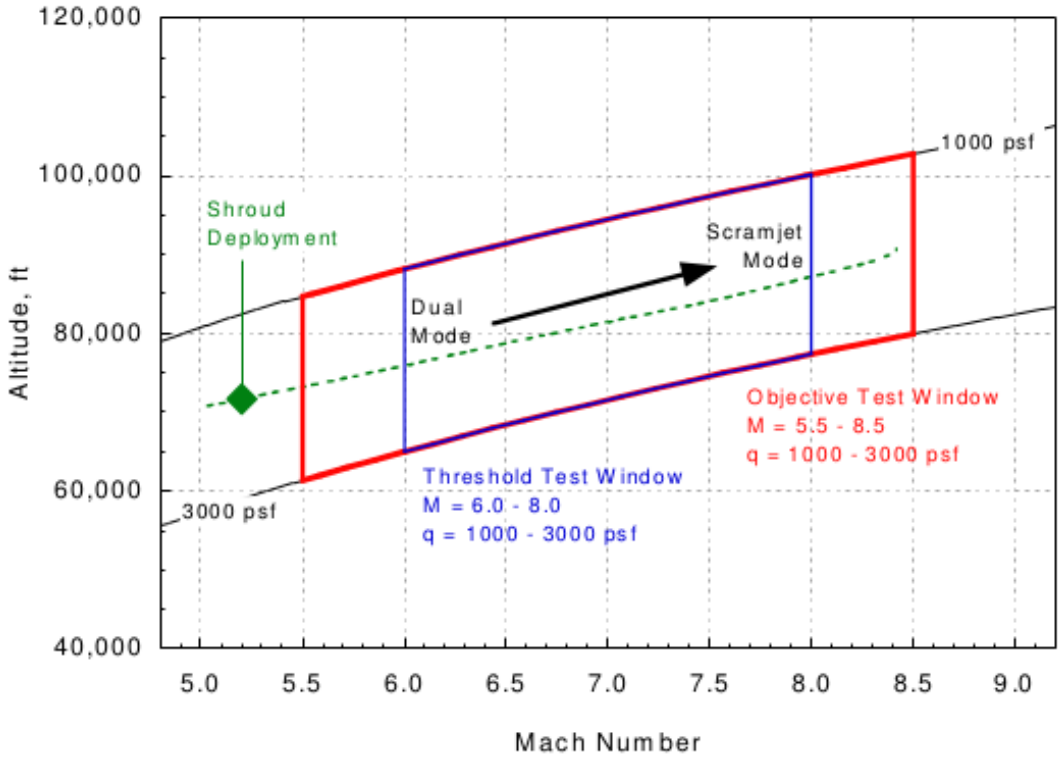
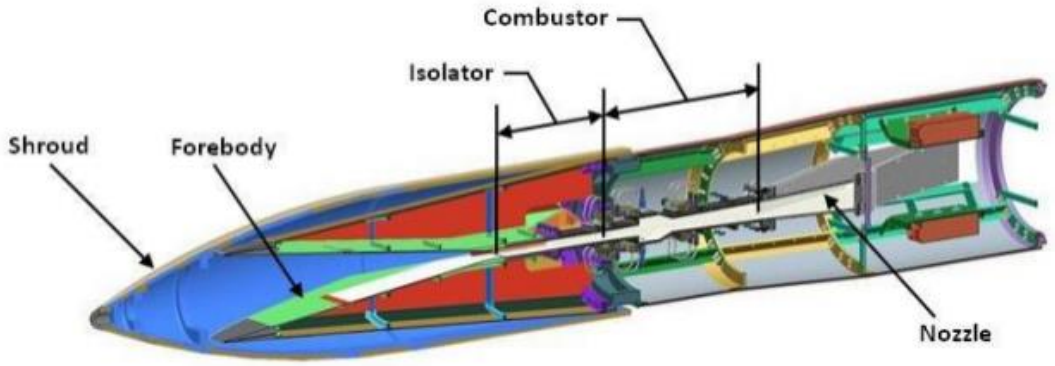
HiFIRE Scramjet（超燃冲压发动机）

- Air, ~85 kPa, 725K, M=2.51 (Mach 6.5 flight conditions)
  - “Dual-Mode” - partially supersonic combustion
- Fuel: Ethylene (64% 乙烯) - Methane (36% 甲烷)

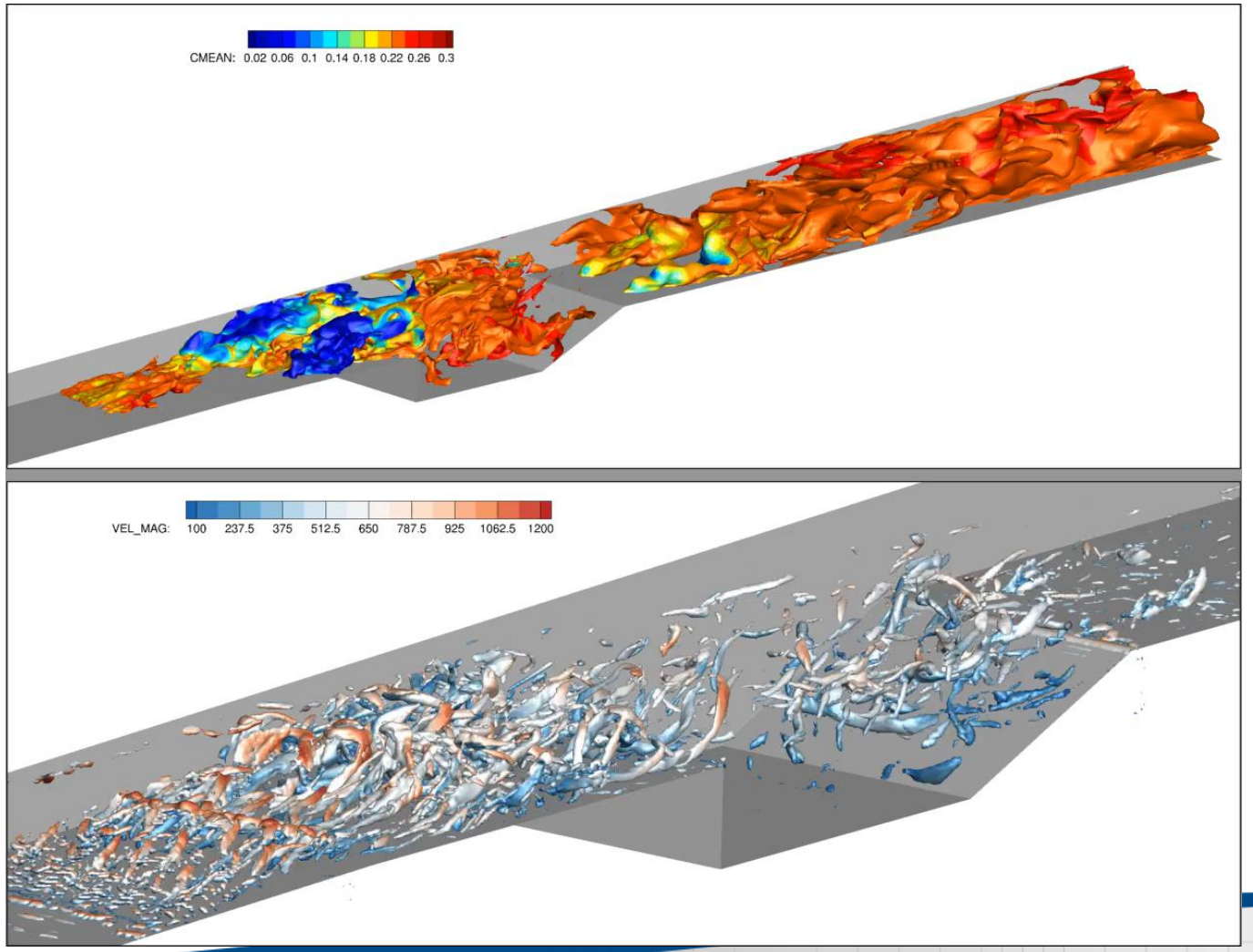




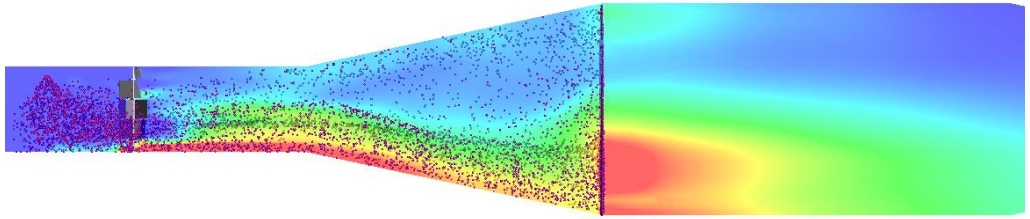


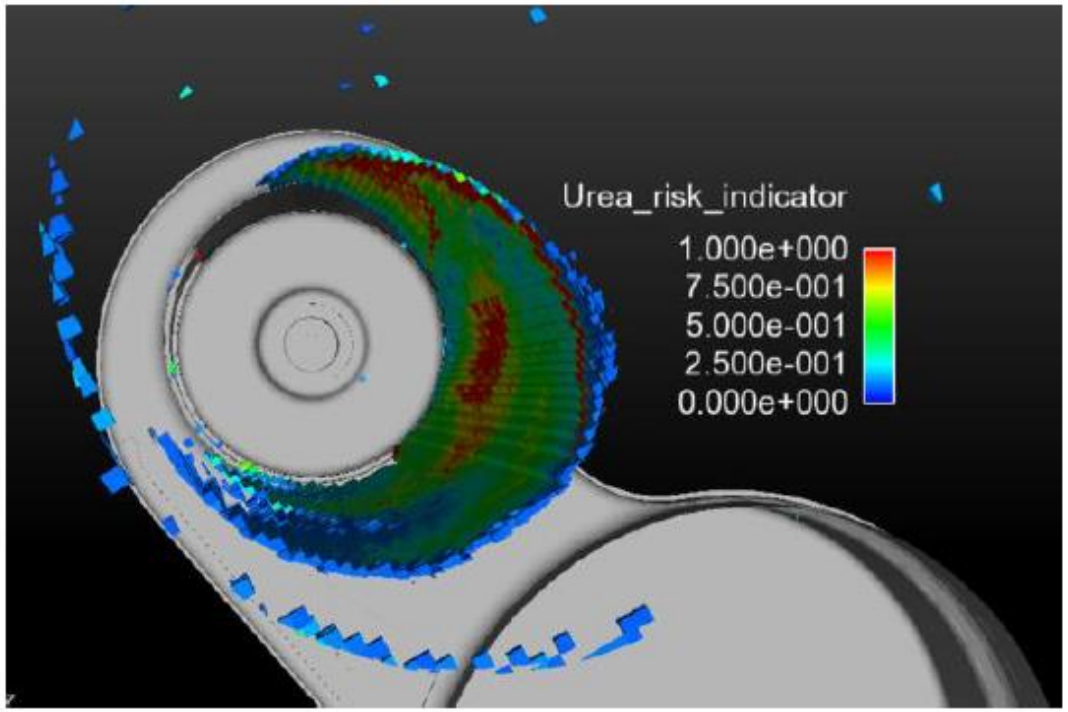
Bottom Figures: Cabell et al., AIAA 2011-2248

Initial Scramjet Results: Ignition（点火）



Engine Aftertreatment（发动机后处理）：





Fixed Flow/Combine Parcels for Accelerated AT Simulations（单项耦合和粒子合并来加速后处理计算）

- Take advantage of the flow similarity between spray pulses
  - When fixed flow is activated:
    - Mass, momentum, species, turbulence are no longer solved
    - Most recent values of velocity, species, turbulence prevail
    - Energy conservation and spray/film continues to be solved
    - Very large dt can be used with no stability concerns
    - Solver runs very fast (dramatically reduced workload)
- When modeling many spray pulses, the number of film parcels becomes very large, and tracking effort becomes very large
  - When combine parcels is activated:
    - Combine large numbers of film parcels for reduced runtime and RAM
    - Preserves the net mass, species composition, and energy of the film
    - Provides a mechanism to mix the contents of old and new parcels

Simulation time per day on commercial geometries

Approach	Simulated Time Before	Simulated Time After
Molten Solid	10 s/day	30 s/day
Detailed Decomposition	1 s/day	30 s/day

Validating Fixed Flow: Birkhold

SAE TECHNICAL PAPER SERIES 2006-01-0643

Analysis of the Injection of Urea-Water-Solution for Automotive SCR DeNOx-Systems: Modeling of Two-Phase Flow and Spray/Wall-Interaction

Felix Birkhold, Ulrich Meingast and Peter Wassermann
Robert Bosch GmbH

Olaf Deutschmann
Institute for Chemical Technology and Polymer Chemistry, University of Karlsruhe

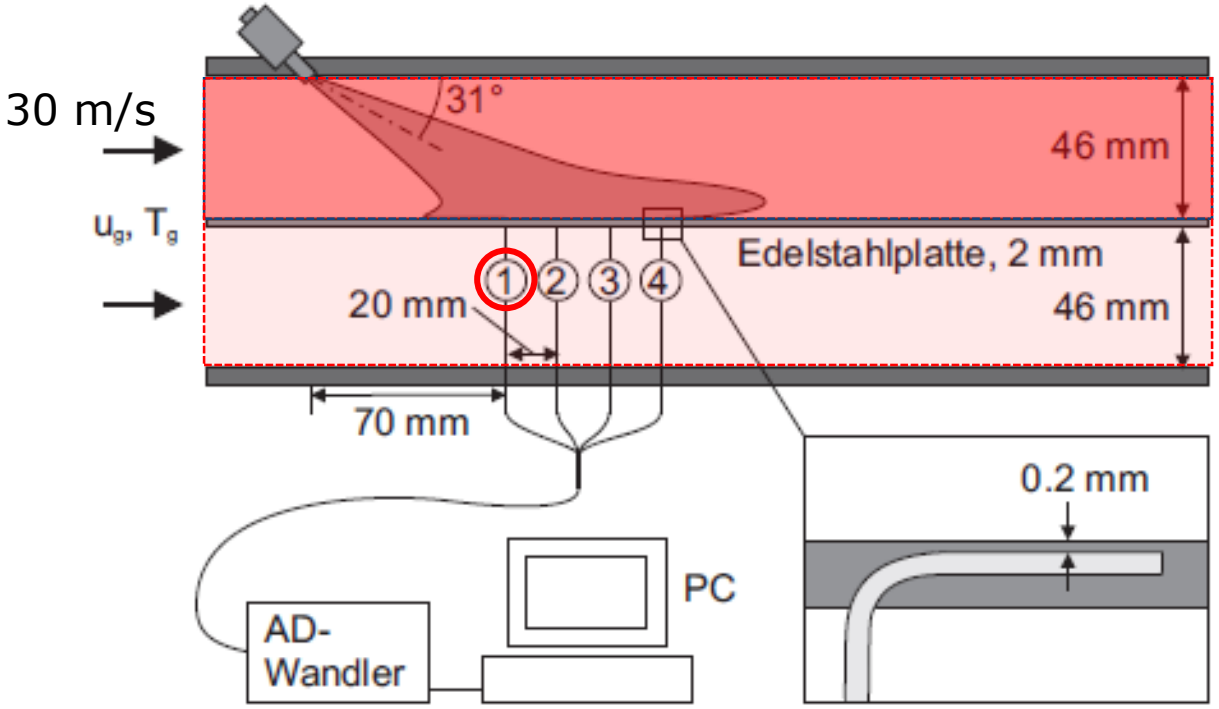
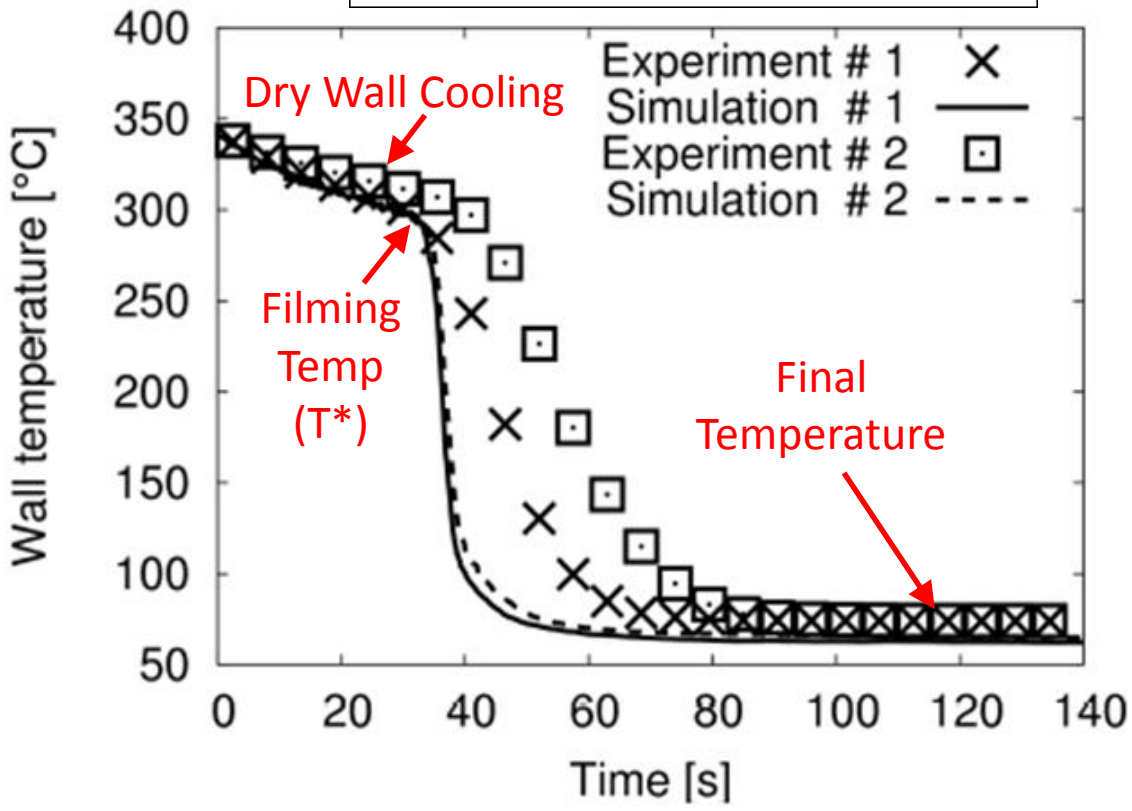


Abbildung 5.12: Aufbau zur Temperaturmessung bei der Spraykühlung



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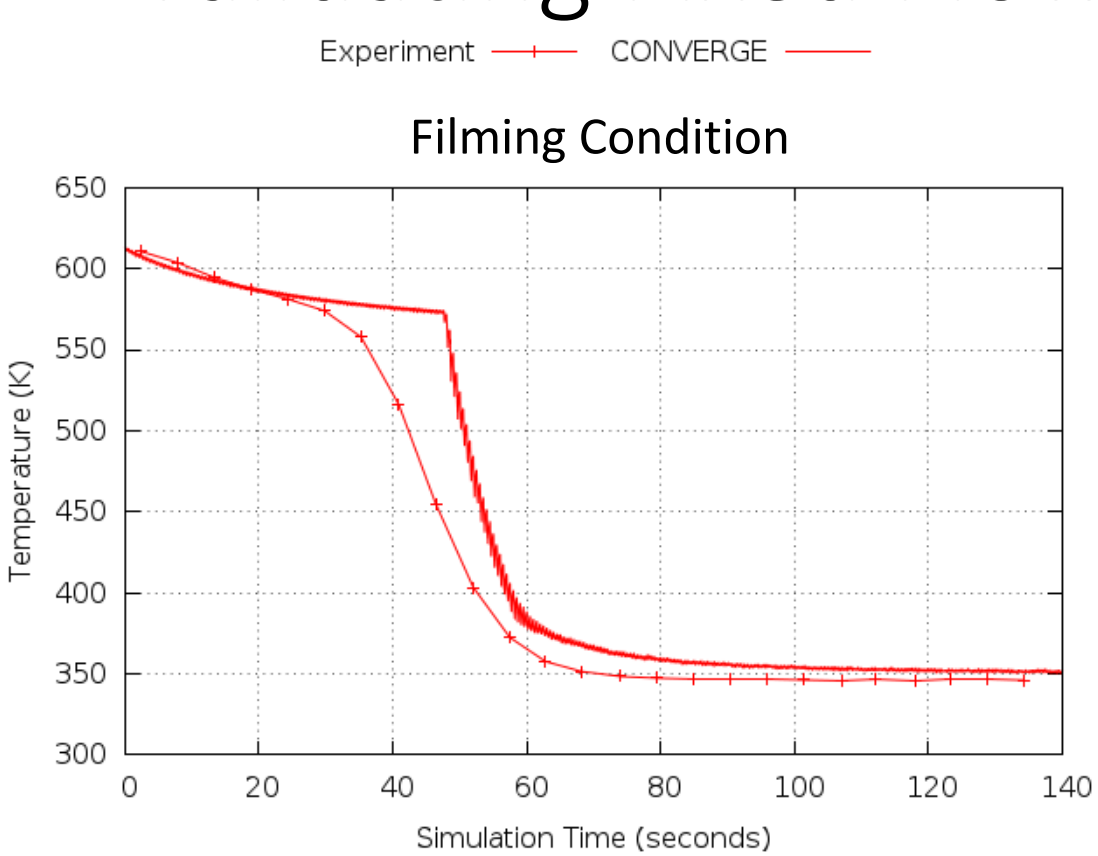
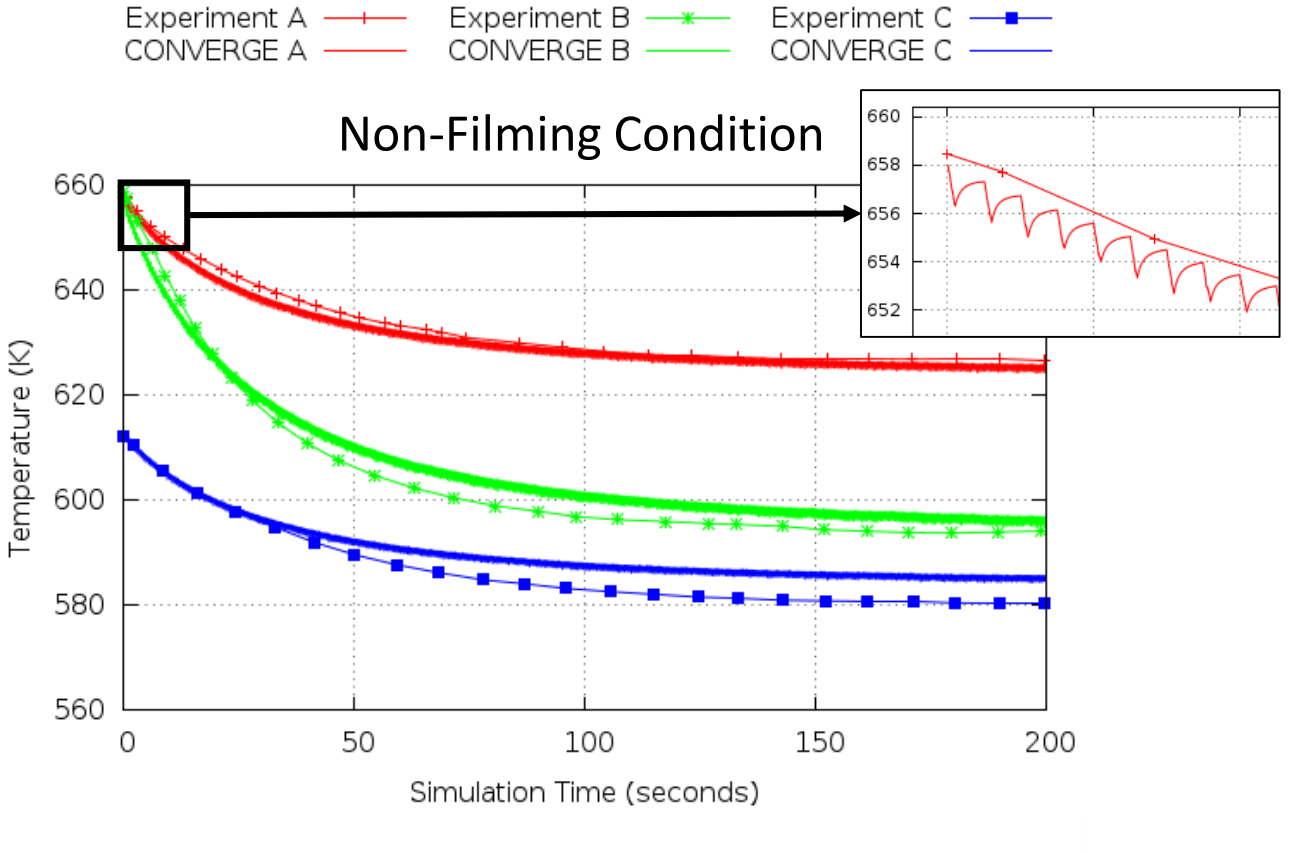
Validating Fixed Flow

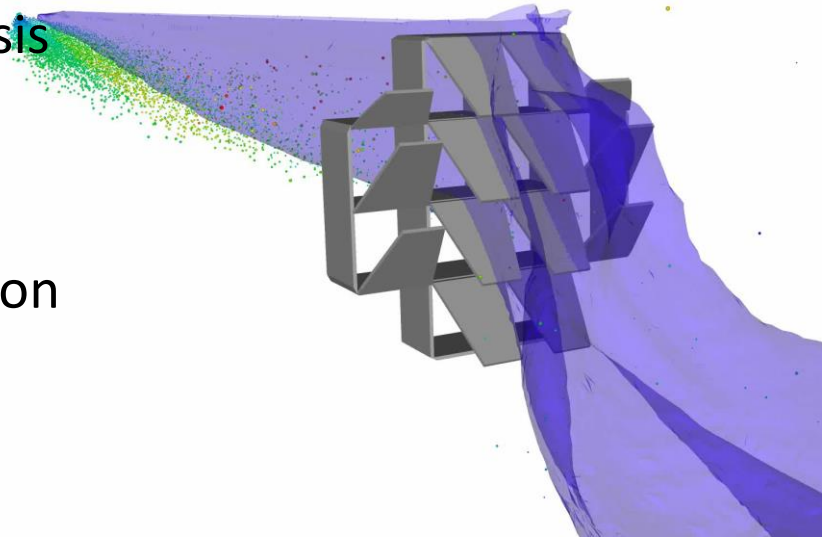




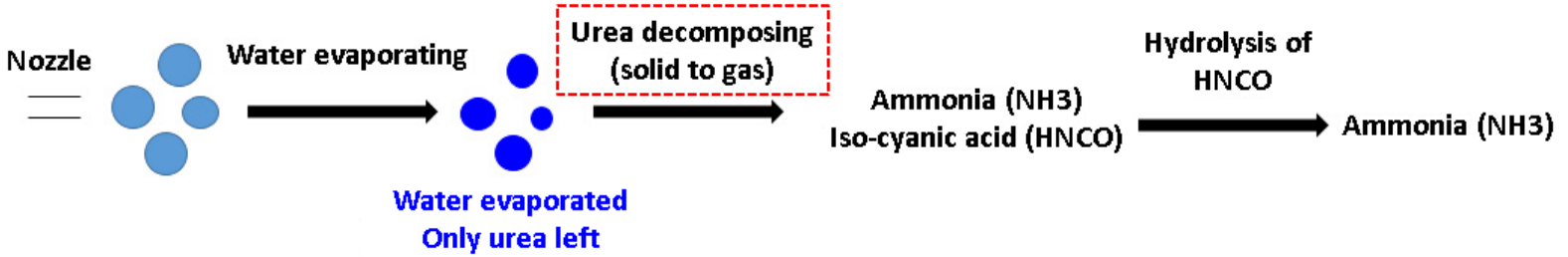
- Birkhold et al. reduced metal specific heat by 150 times; stretched time axis from $1^1/_3$ to 200 seconds
- Our simulation (right) solves 200 seconds of physical time
  - Every spray pulse (200 X 2 Hz = 400 pulses), of duration 0.2 seconds is resolved
  - Resolve transient temperature history

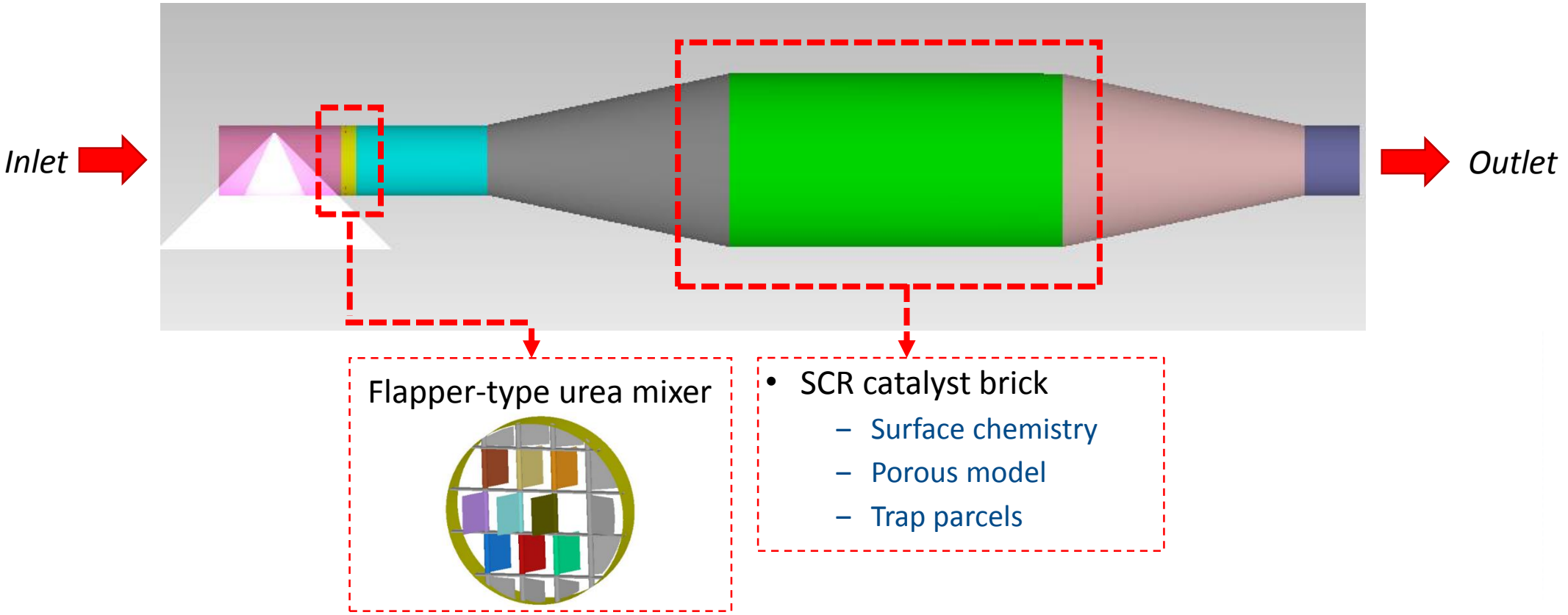
Optimization of Urea/SCR Mixer Design （SCR尿素混合器的优化设计）

- CONVERGE CFD and ESTECO's *mode*FRONTIER optimization
- Diesel Emissions Fluid injection (DEF)
  - Atomization, evaporation, thermal decomposition, hydrolysis
  - Final reducing agent -> Ammonia (NH3)
- Key design considerations for Urea/SCR systems
  - Reductant uniformity into catalyst -> Efficient NOx conversion
  - Minimal pressure drop for optimum engine performance
  - Urea dosage, ammonia slip
- Role of urea mixers
  - Urea decomposition -> Mix, break and help evaporate
  - Great influence on flow characteristics, SCR performance/NOx conversion



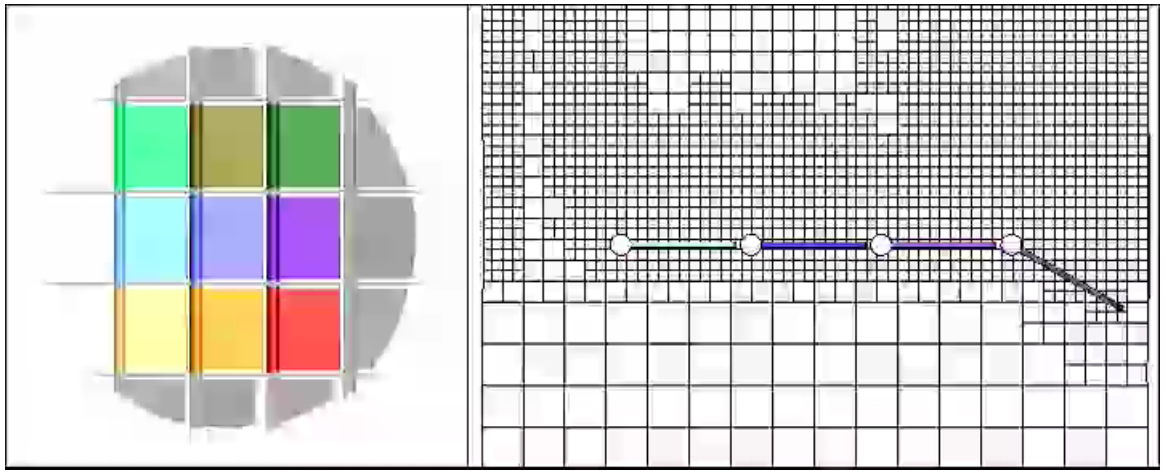
Urea/SCR Case





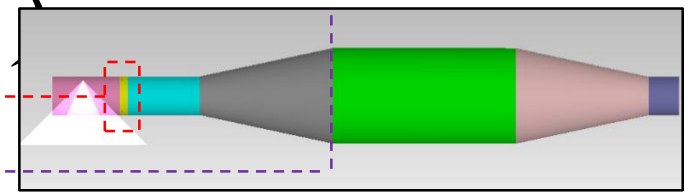
Automated Surface and Mesh Generation（自动几何表面和网格生成）

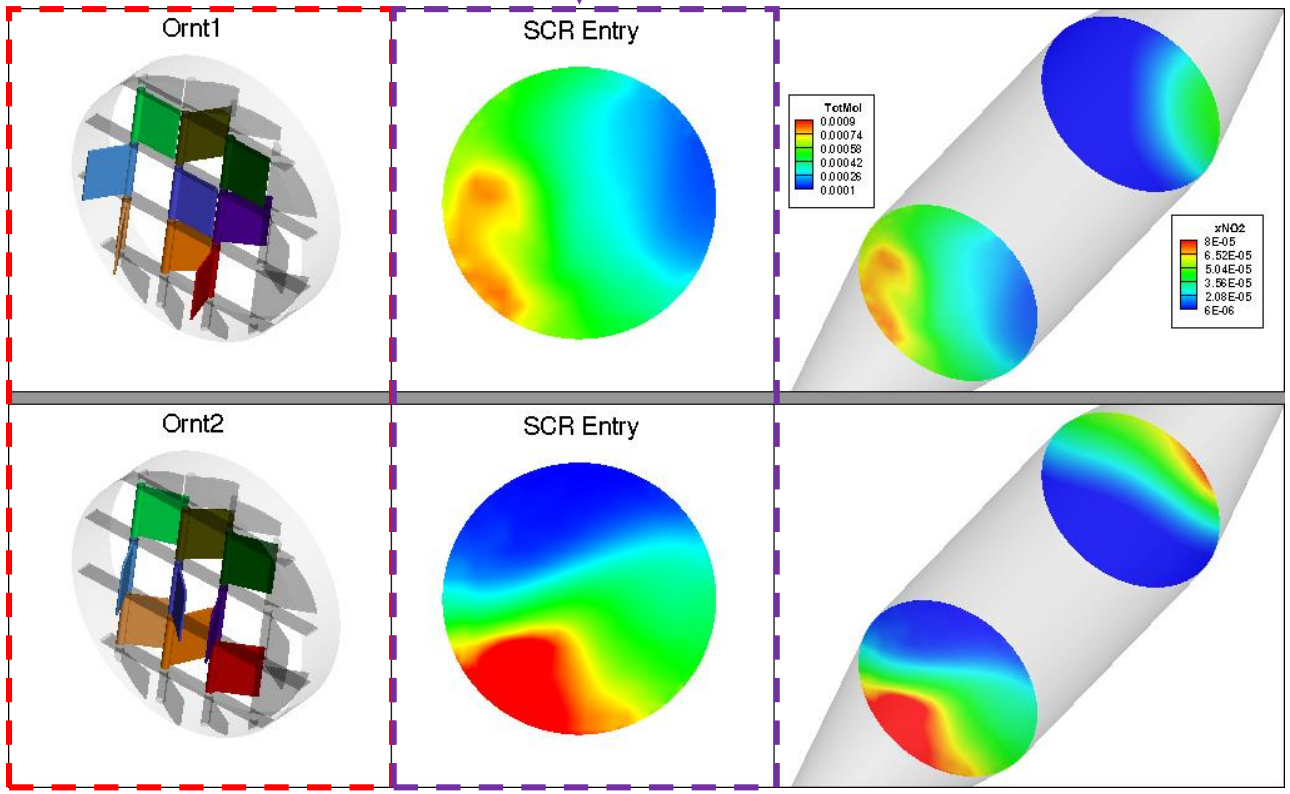
- Automate generation of surface files
  - Vertex locations of selected boundaries updated within surface file
  - Quick generation through user terminal
- Automated meshing in CONVERGE
  - Cartesian cut-cell approach
  - Preserve original volume
  - Well suited for moving/changing surfaces
  - Update surface file only
- Refinement strategies
  - Fixed embedding
  - Adaptive mesh refinement (runtime)



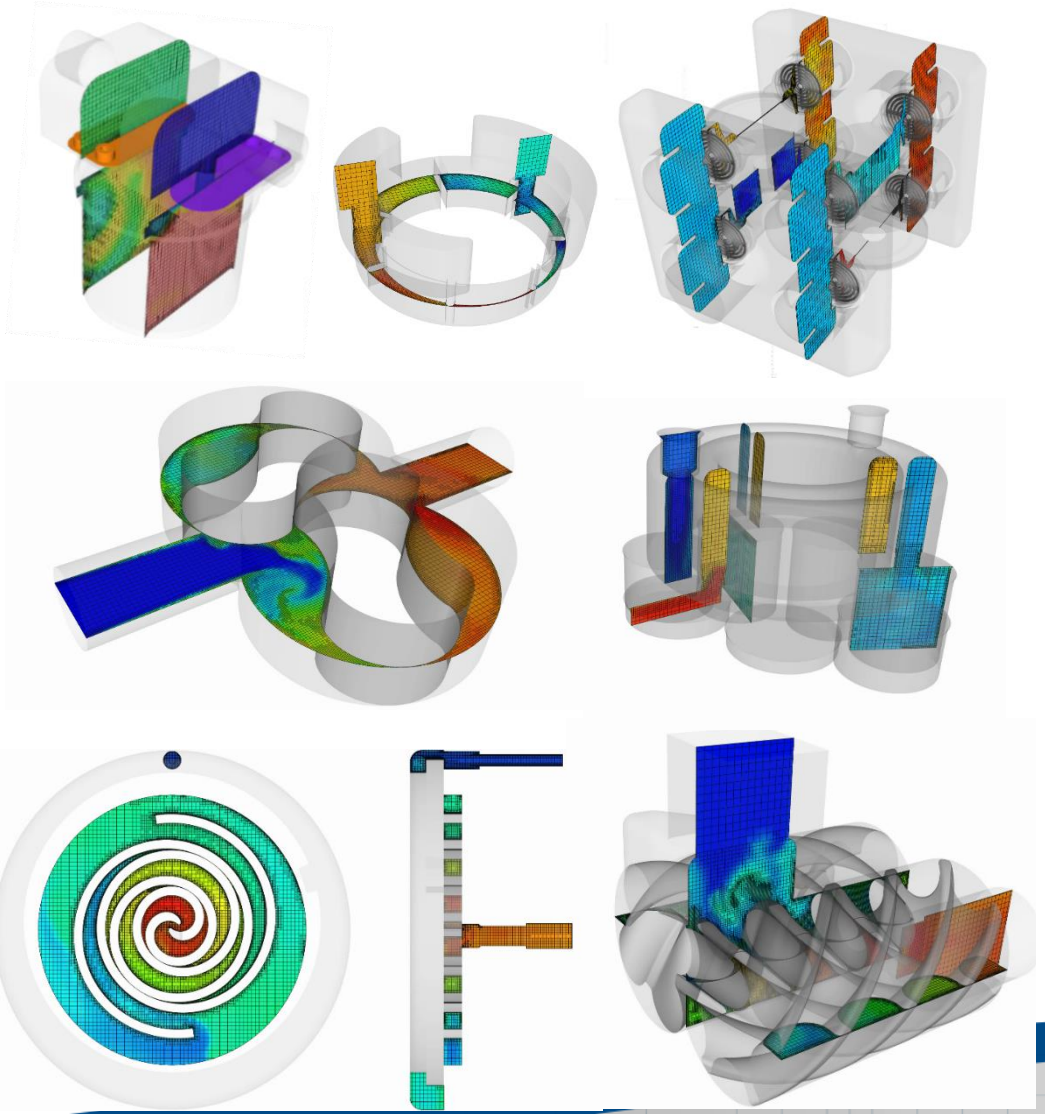
Optimization Results（优化结果）

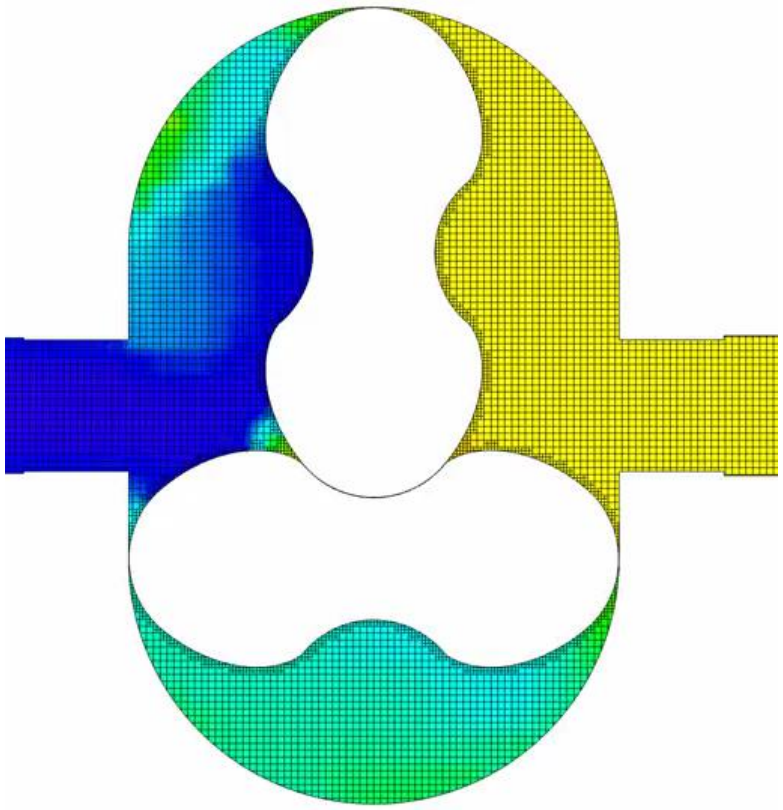
- Two mixer blade orientations
  - Ornt1
  - Ornt2
- Uniformity at SCR Inlet
  - Ornt1 **GOOD**
  - Ornt2 **POOR**
- NOx reduction in SCR
  - Lack of NH3 -> Poor NOx conversion



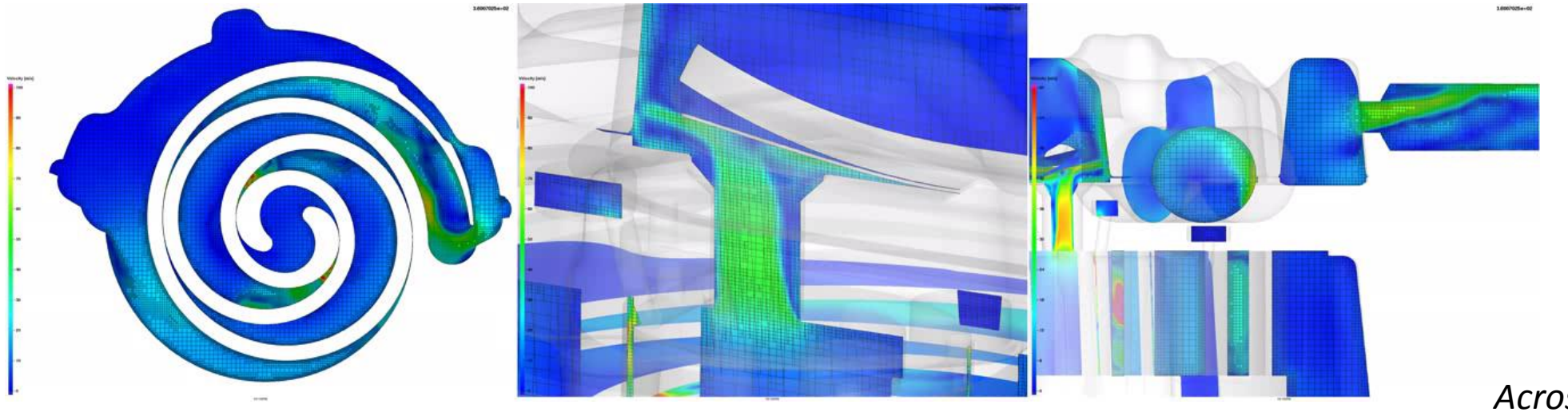


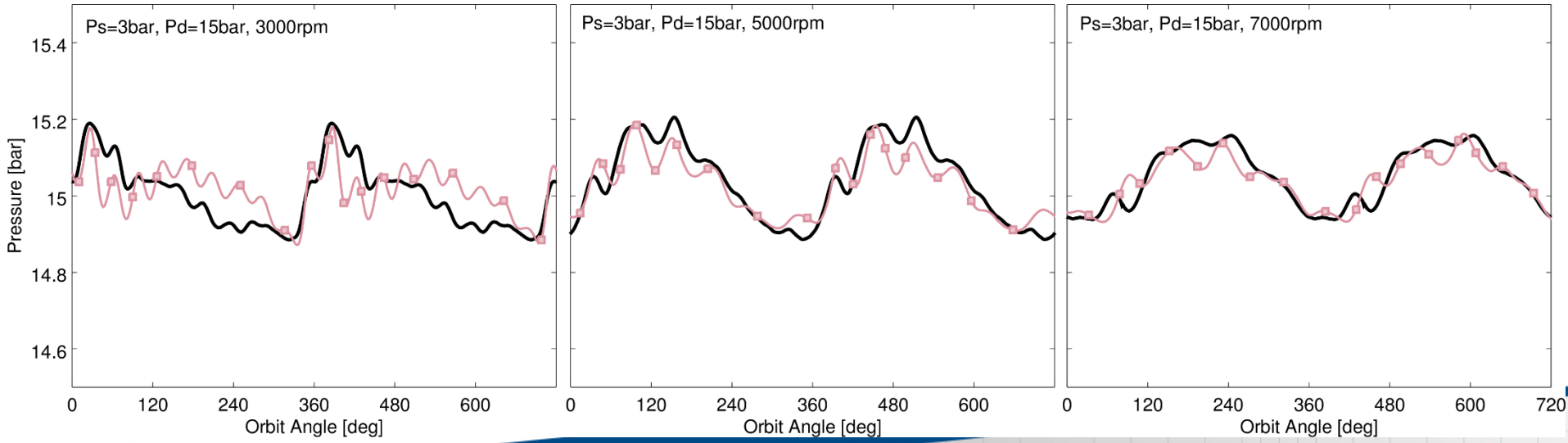
Pumps and Compressors（泵和压缩机）：





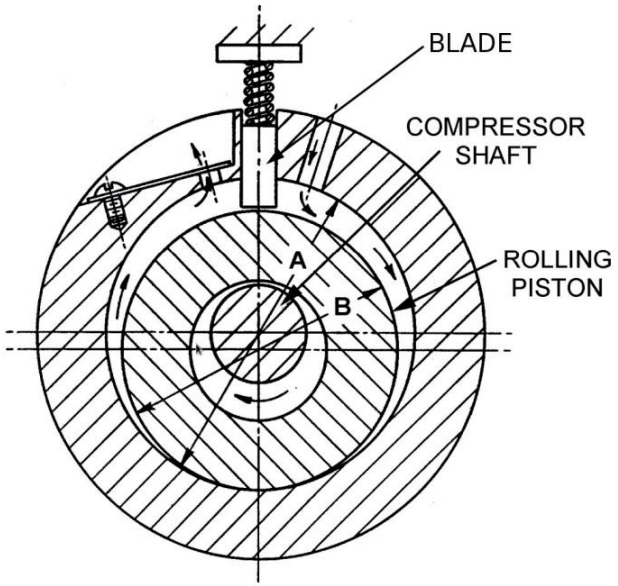
Scroll Compressor（涡旋压缩机）

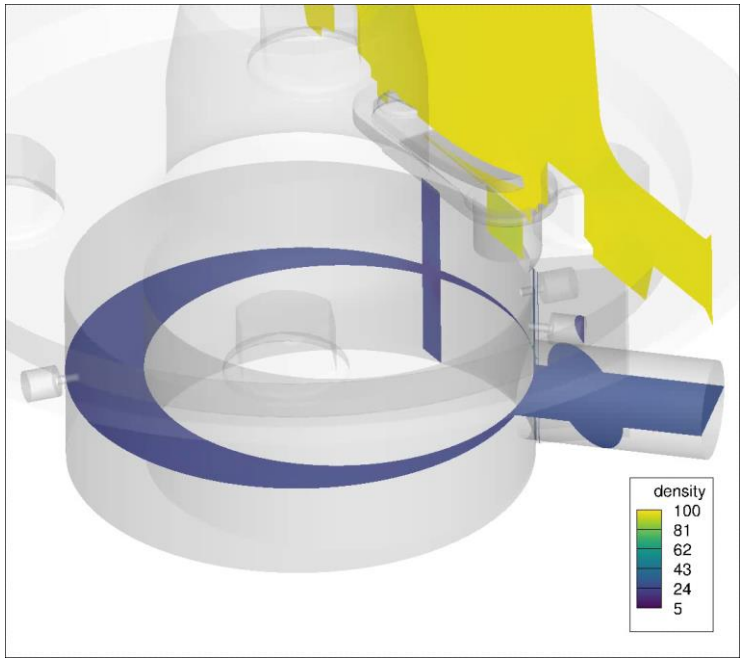


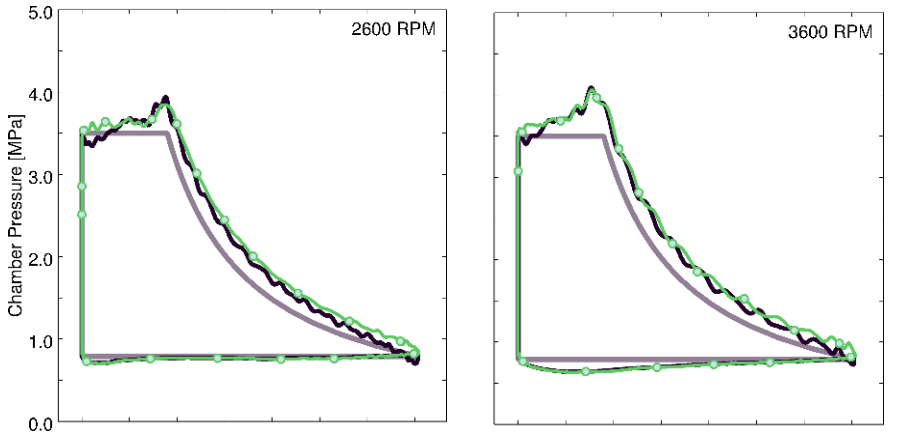


Across all speeds, the overall amplitude and frequency of the discharge pressure pulsation is well predicted by the CFD model

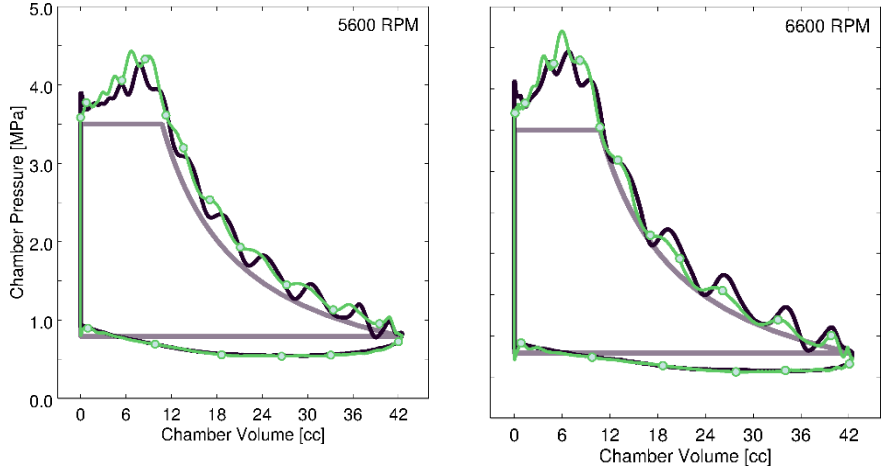
Rolling Piston Compressor

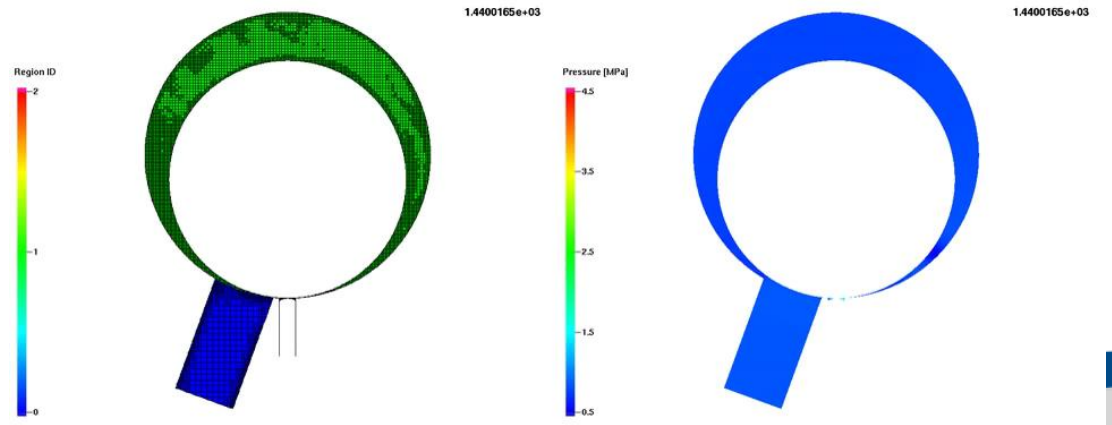






- Good agreement with experimental data
  - Experiment
  - CONVERGE CFD





Conclusions（结论）

- The enhanced capabilities in CONVERGE v3.0
  - Improved Scaling（可扩展性）
  - Improved memory usage（低内存)
  - Inlaid mesh（镶嵌网格）
  - Fixed flow（单项耦合）
- 以上V3.0的这些改进+自动网格生成，使CONVERGE可以应用在内燃机以外的各种领域!

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