http://www.cradle.co.jp/

More Innovation Using SC/Tetra, the Innovative CFD Software

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General Manager at Cradle North America, Inc.

CRADLE

A table of contents

Corporate Profile

Establishment: **1984**

Offices:

Headquarters:	**Osaka, Japan**
Branch Office:	**Tokyo, Japan**
Subsidiary:	**Dayton, OH USA**

Headquarters
Osaka, Japan

Worldwide Distributors:

- 4 main distributors:

Taiwan, China, Korea, France

- Other resellers

Cradle North America, Inc.
Dayton, OH

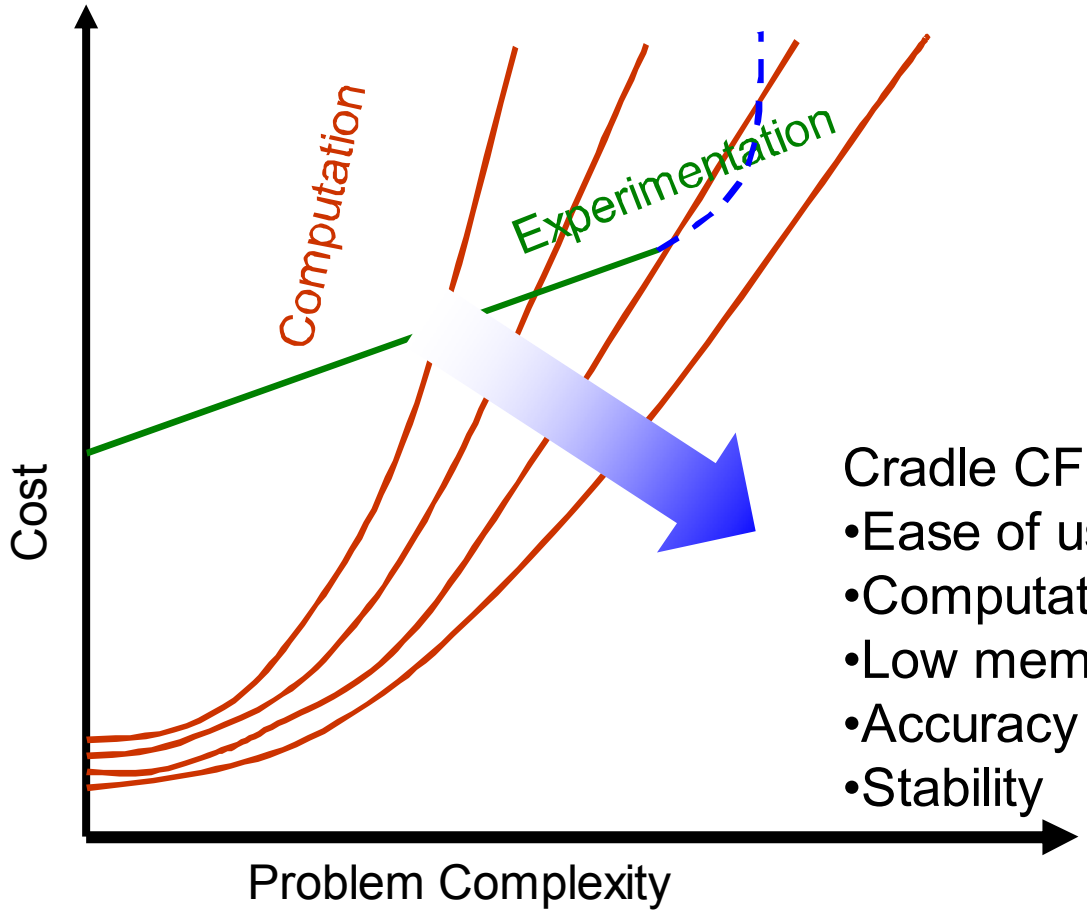
Tokyo, Japan

Business

- Software Development
  - CFD
  - Structural Analysis (FEA) to aid FSI
  - Data cleaning and modification software
  - Optimization
- Trainings and seminars
- Technical Support
- Engineering Services
  - Simulation service
  - Consultation
  - Customization
  - Automation

Software Development Policy

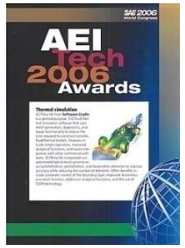
Experimentation cost vs. computation cost



Cradle CFD's priorities:
- Ease of use
- Computation Speed
- Low memory usage
- Accuracy
- Stability

Cradle's concept is to provide a tool which aids a company to market a better product in a shorter lead time.

Awards

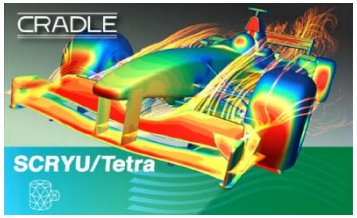


- **2002: Won JSME award (The Japan Society of Mechanical Engineering)**
- **2005: Awarded by METI (Ministry of Economy, Trade and Industry of Japan)**
- **2006: Won AEI2006 Tech Awards (Automotive Engineering International)**
- **2007: Certification of Visualization Award (APCOM 2007)**
- **2009: Best CFD Graphics Award (The Japan Society of Fluid Mechanics)**

Products

CFD

MAIN INDUSTRIES:



Multi-purpose CFD
Unstructured Mesh
SC/Tetra

Automotive / Aerospace
Marine / Machinery /
Energy / Electrical Appliances
Oil & Gas / Bio-medicals

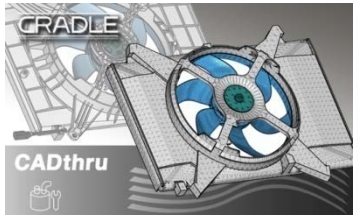
* SCTSruct Option: Steady State Linear structure analysis

Multi-purpose CFD
Structured Mesh
scSTREAM

HEAT Designer

Buildings & Architectures /
Civil & Oceanic engineering /
Electronics Applications

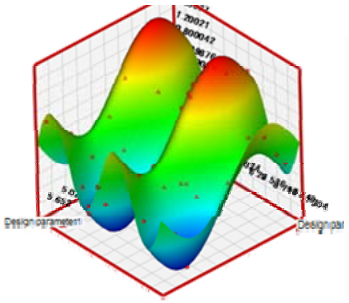
Advanced Data Cleaning Tool



CADthru

- Data Cleaning
- Data Modification

Optimization

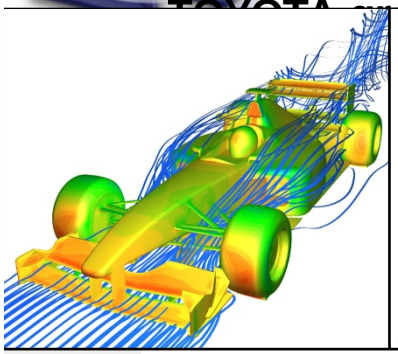
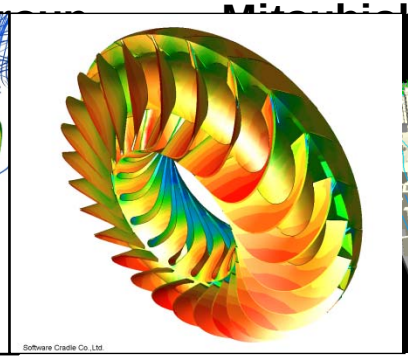
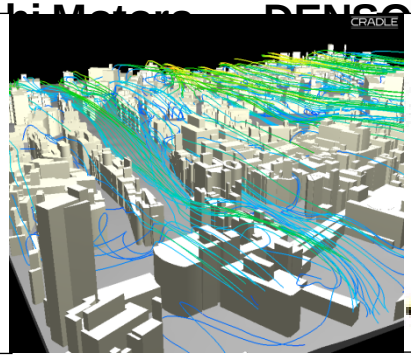
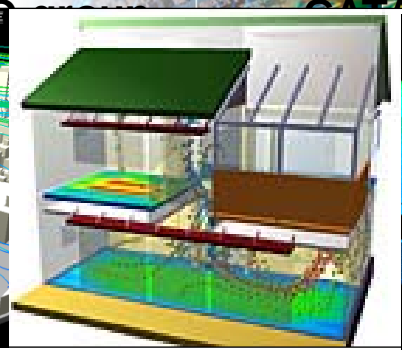
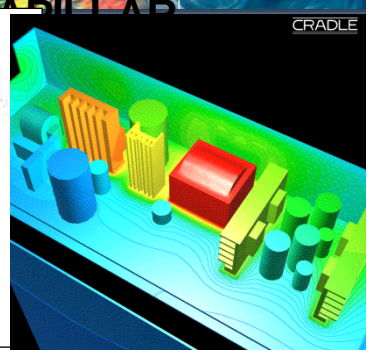


Optimization Option

- Multi Objective
- Genetic Algorithm

Customers

Automotive

TOYOTA group | Mitsubishi Motors | DENSO group | CATERPILLAR

Mazda Motor | AISIN group | COPELAND

Electronics & Electrical Appliances

More than 800 companies & organizations worldwide

Panasonic group
SANYO group
SHARP Corporation
SONY group

IBM Japan Ltd.
NEC group
Hitachi group
Mitsubishi group
Toshiba group

Samsung
Sumitomo Electric group
Fujitsu group
Oki Electric group

RICOH group
Pioneer Corporation

Industrial Equipments & Machinery

Ishikawajima-shibaura machinery Co.,Ltd.
Hitachi Zosen Corporation
Hitachi Plant Engineering & Construction Co.,Ltd.
Kawasaki Heavy Industries, Ltd.
Mitsubishi Heavy Industries

Komatsu Ltd.
Murata Machinery, Ltd.
Nidec Corporation
Hitachi Koki Co., Ltd.
Nakashima Propeller Co, Ltd.
NTN Corporation
SEKISO Industry Co., Ltd.

Mitsui Engineering & Shipbuilding Company, Limited
Nippon Koei Co., Ltd.
Schlumberger Limited
Toyo Engineering Corporation

Technical Sponsorship

DOME

Toda Racing

M-TEC

Dandelion Racing

1.Introduction to SOFTWARE CRADLE

- How CRADLE software contributes in innovation

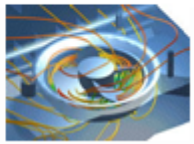
2. Introduction to Cradle CFD software

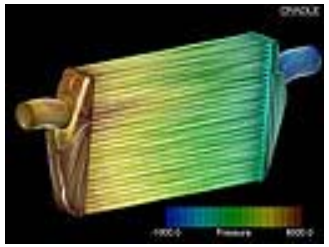
2-1. SC/Tetra

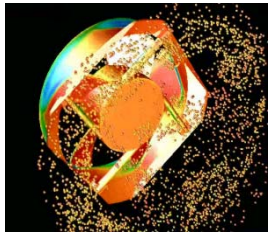
Introduction to SC/Tetra

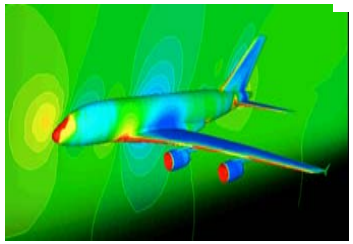
Multi-Purpose CFD Software
with Unstructured Mesh

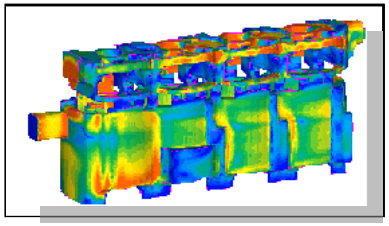
SC/Tetra

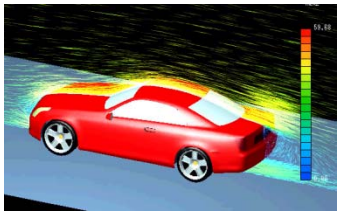












General:

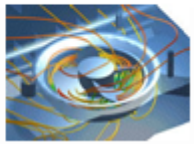
All-in-one package CFD software consisted of :

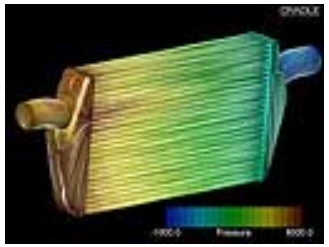
- ***Preprocessor***
- ***Solver***
  - ***pressure based FVM***
  - ***density based FVM***
- ***Postprocessor***
- ***Data mapping Tool to FEA meshes***
- *Linear structural analysis FEM solver (Option)*
- *Direct coupling I/F with Abaqus for transient FSI (Option)*

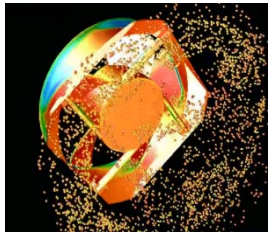
Introduction to SC/Tetra

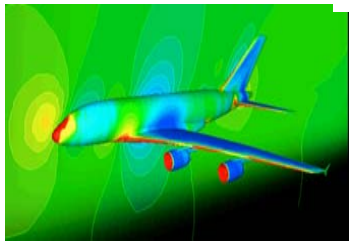
Multi-Purpose CFD Software
with Unstructured Mesh

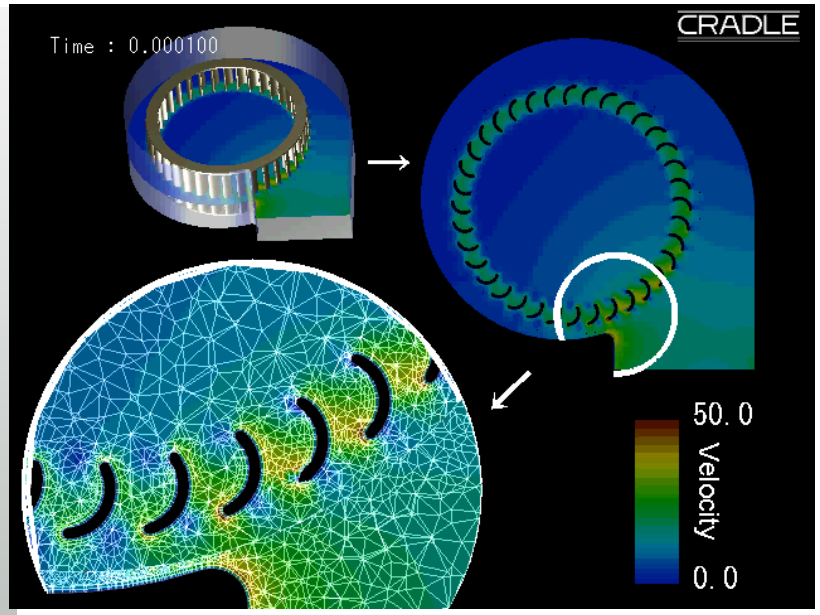
SC/Tetra

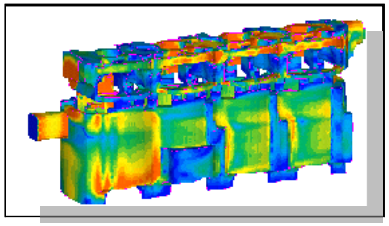


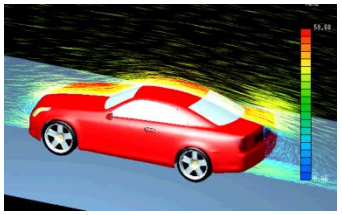












Mesh Related Technology

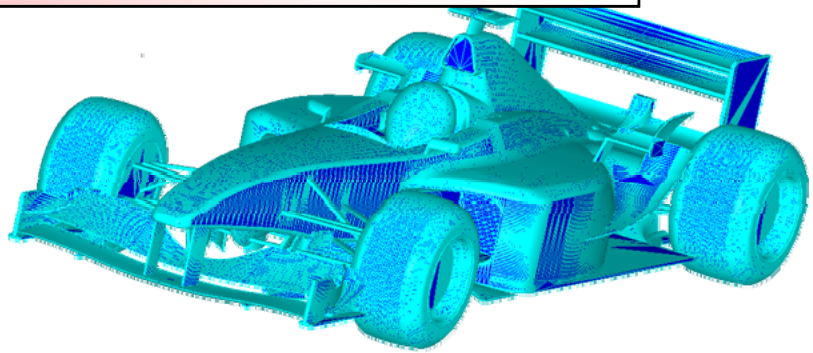
- Overset mesh
- Arbitrary Lagrangian-Eulerian (ALE)
- Passive motion control
- Adaptive mesh refinement

Physical Model:

- Compressible / Incompressible flow
- Newtonian and Non-Newtonian fluid
- Heat radiation / Solar radiation
- Multi-phase / Free surface flow /Particle tracking
- Humidity / Condensation / Solidification / Melting
- Diffusion / Chemical reaction / Combustion
- LES / Porous media / Cavitation
- Thermoregulatory model
- DES/ VLES / 12 more turbulence models
- Fan model / Thermal conduction panel
- Joule Heating / Aero Acoustic
- Simple Linear Structural Analysis
- 2-way Fluid Structure Interaction with Abaqus

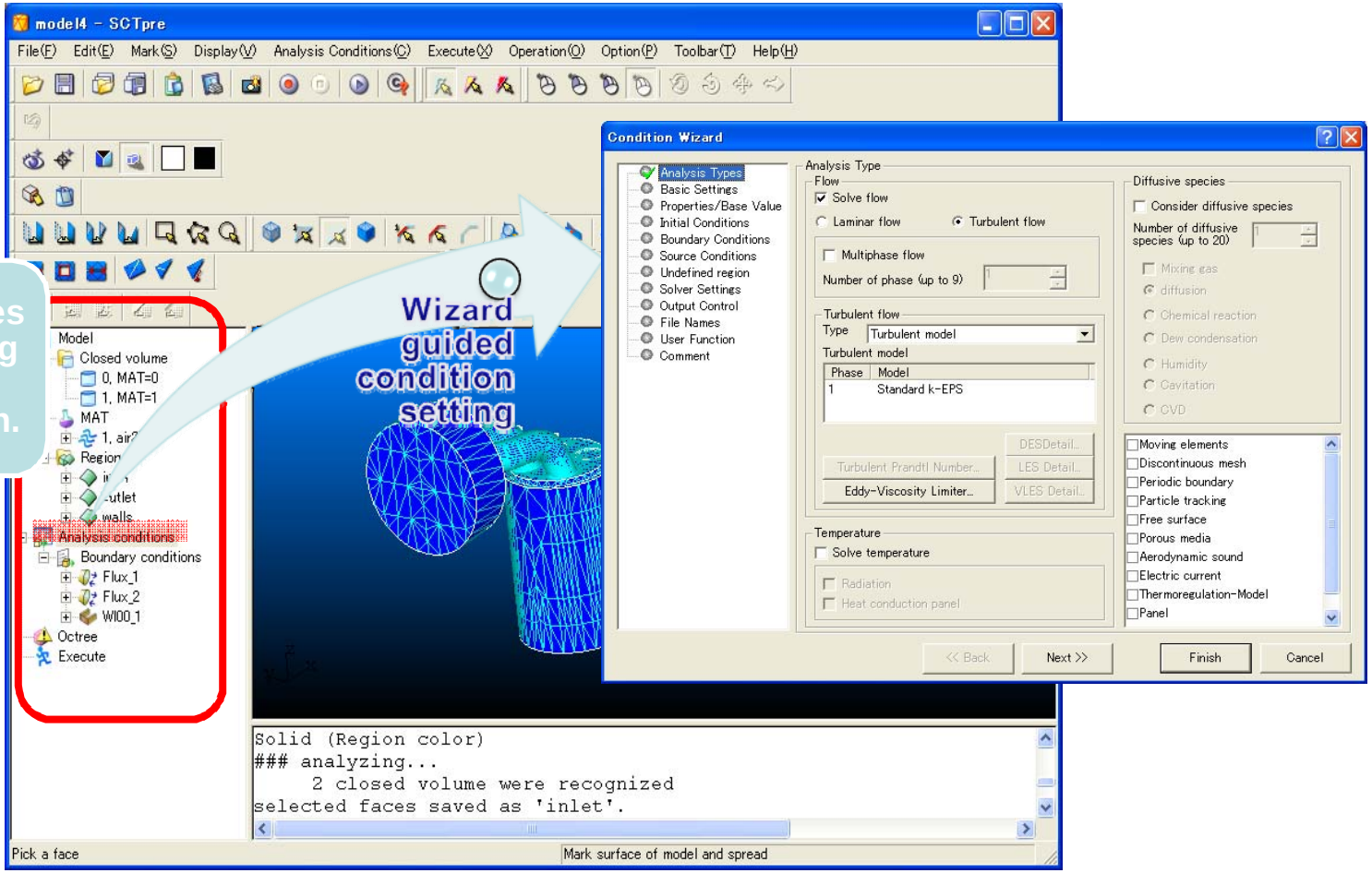
Outstanding Features of SC/Tetra

- User Friendly Interface and Usability
- Fast-Robust-Intuitive Mesher
- Low Memory Consumption
- Outstanding Computation Speed and Accuracy
- State of the art Postprocessor
- Parallel Pre/Solve(CFD & Structure)/Post



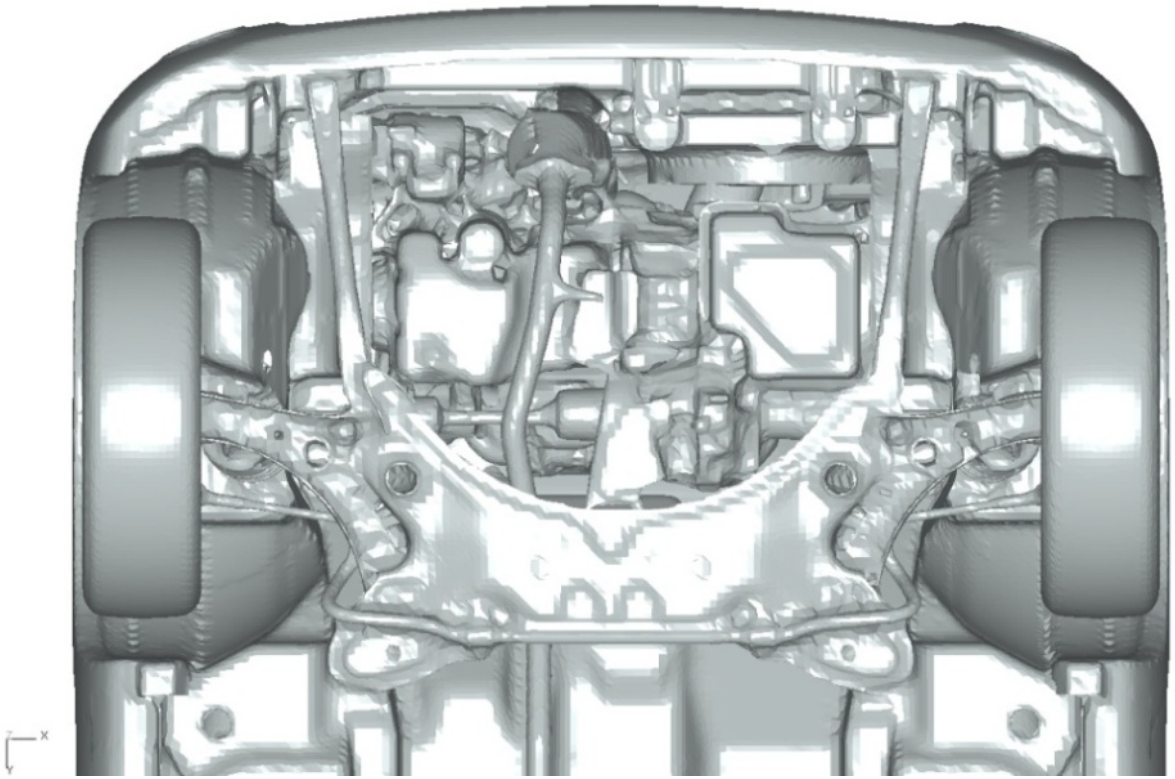
User Friendly Interface and Usability - *Navigation*

Navigation that guides a user from importing a geometry to executing calculation.



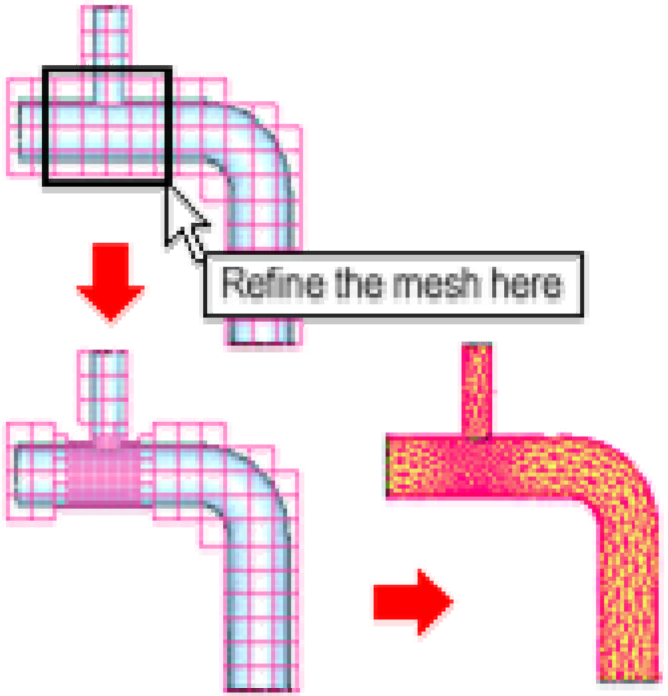
User Friendly Interface and Usability – *Wrapping*

In addition to various surface cleaning functions, wrapping function is available to remove unwanted features and geometrical error. The octree is used for the resolution of wrapping, therefore, the size of the octant determine the small feature will be kept or removed.



Fast-Robust-Intuitive Meshing

Mesh resolution can be flexibly controlled using octree



Selection methods:

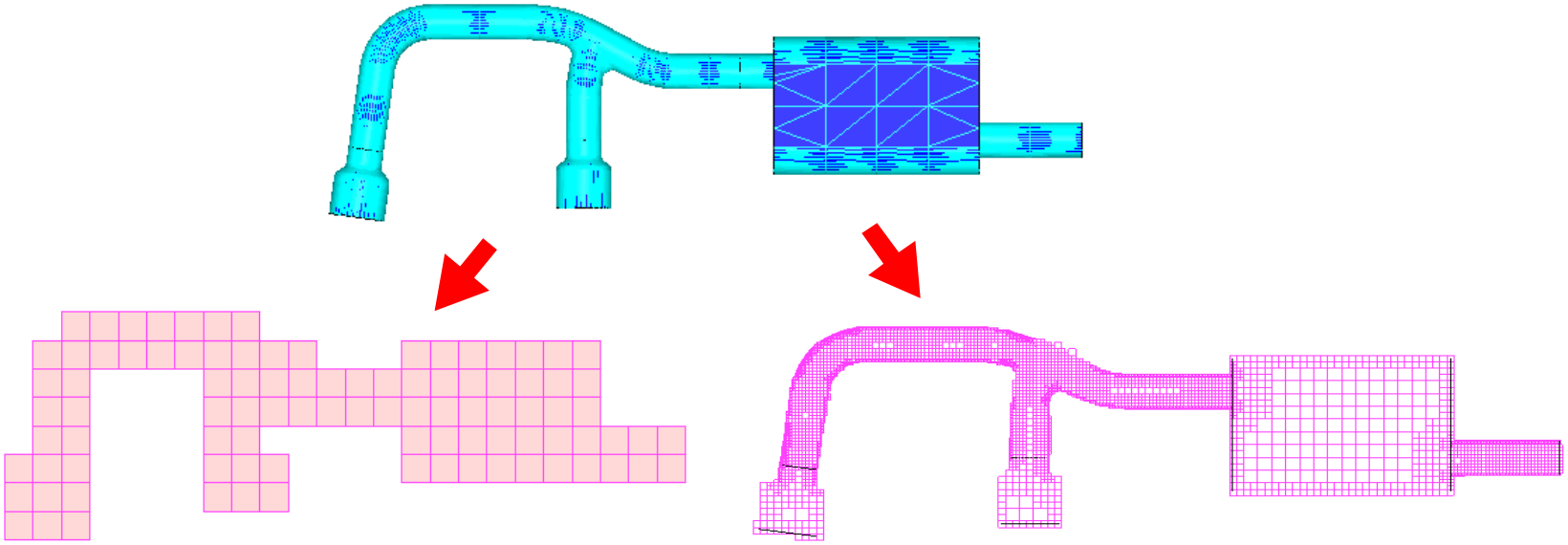
- Rubber box
- Rubber circle
- Rubber arbitrary shape
- Octant size (level)
- Octants adjacent to specified surface
- Octants adjacent to specified edges
- Closed volume
- Material
- Registered surface

Better Accuracy!

Fast-Robust-Intuitive Meshing

Automatic Mesh Resolution Arrangement

Mesh resolution can be automatically arranged according to the geometry by detecting the narrow shape compared to the octants and refining relatively large octants.



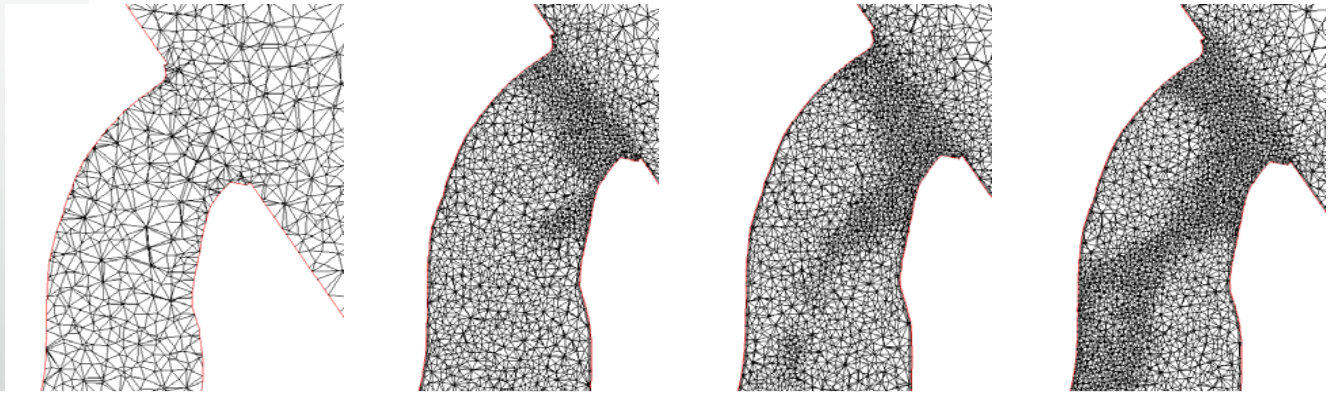
Default

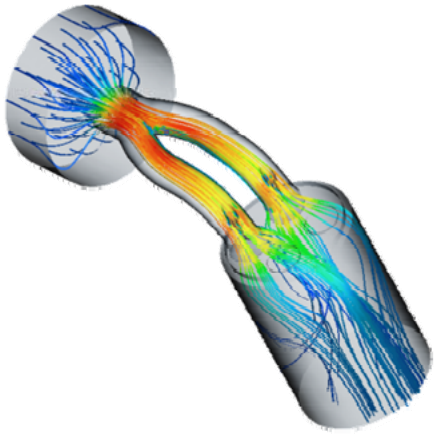
Automatic Mesh Resolution Arrangement

Characteristics of SC/Tetra

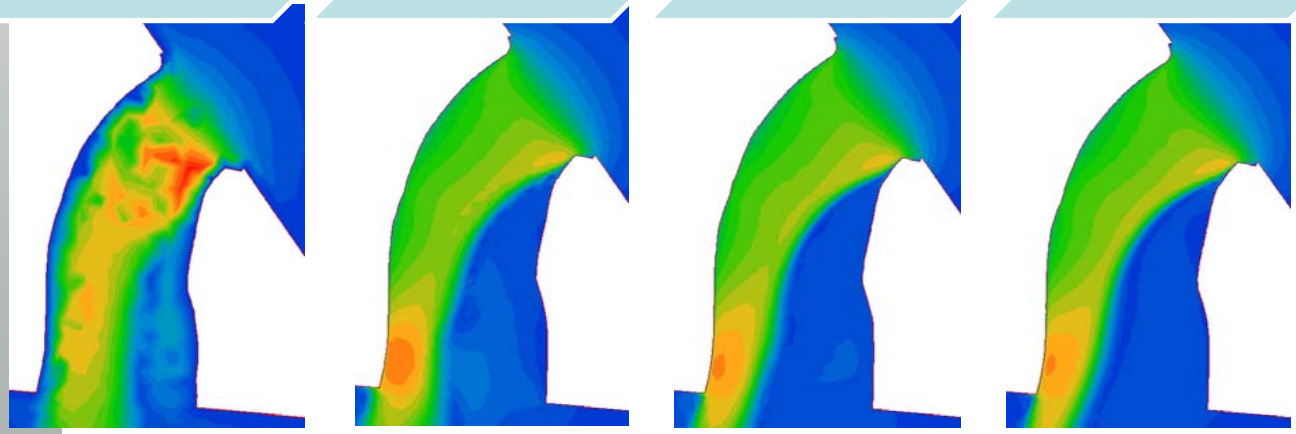
❑ Fast-Robust-Intuitive Mesher

– *Adaptive Mesh Refinement*





1st	2nd	3rd	4th
103,251	285,575	418,165	631,620



# of mesh: 600K
# of cal.: 4 times

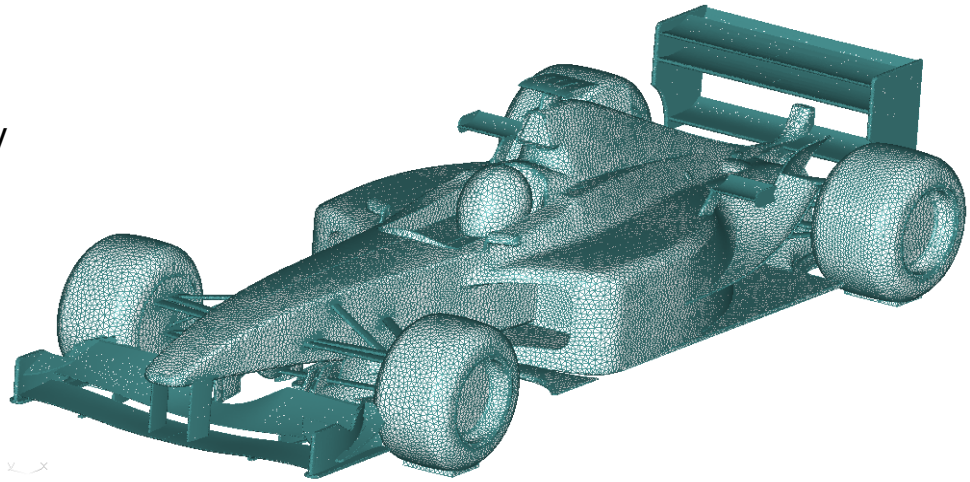
The 3rd and 4th results are almost the same.
This shows that about 420,000 mesh with mesh resolution like the 3rd one is required for certain accuracy.

Fast-Robust-Intuitive Mesher

FAST and ROBUST:

Less than **15 min.** is required to generate **15** million elements including prism layers.

Windows XP x64 edition / 4GB memory
Intel Xeon 5580



Additional functions:

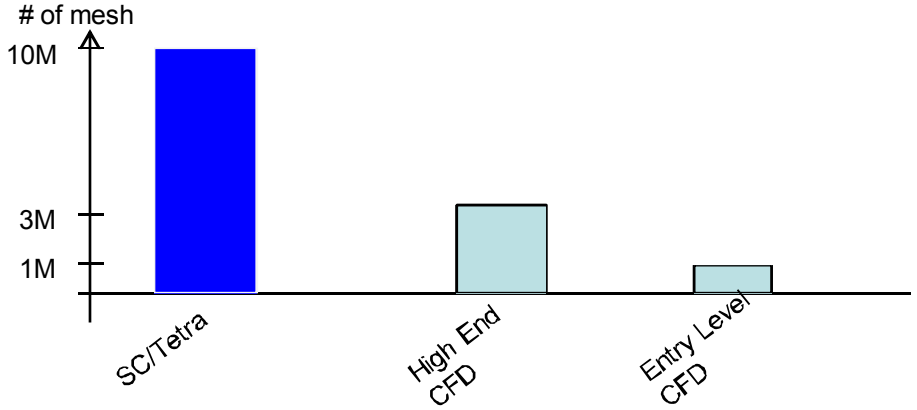
- Smoothing
- Prism layer adjustment (thickness, the # of layers)
- Internal hexa-mesh
- Sweep mesh

Characteristics of SC/Tetra

❑ Low Memory Consumption

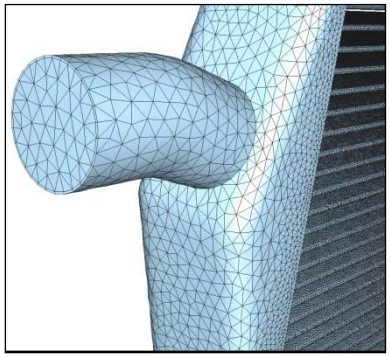
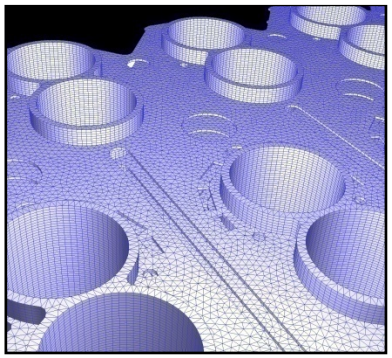
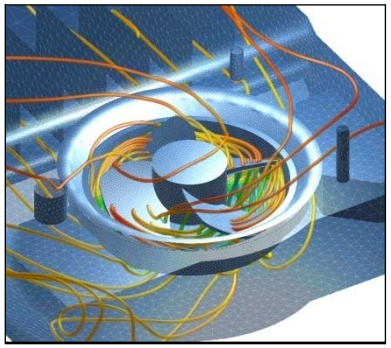
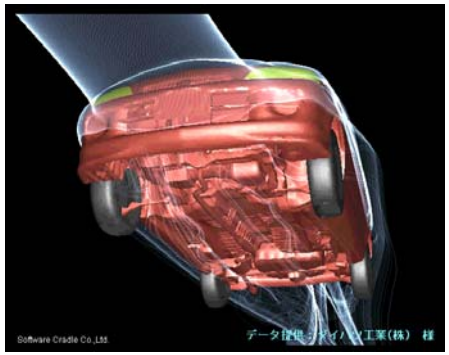
About 5 million elements/1GB!

With 2GB : 10 million elements
With 8GB : 40 million elements
With 32GB: 160 million elements
With 64GB: 320 million elements



Comparison of the # of mesh per 2GB RAM memory

- ***More complicated geometry***
- ***Better accuracy***

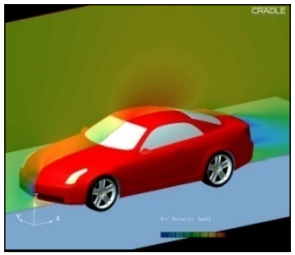
❑ Outstanding Computation Speed and Accuracy

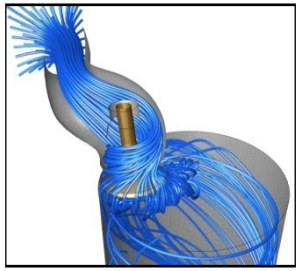
Comparison of Commercial CFD software (2001)

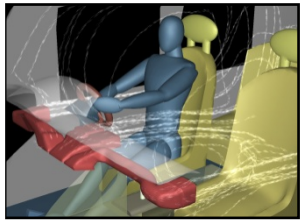
(1) Verification of Aerodynamics
(2) Engine Intake Port Flow
(3) Air-Conditioning Analysis
(4) Air Conditioning Analysis from Defroster Nozzle

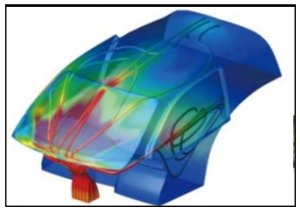
	(1)	(2)	(3)	(4)
SC/Tetra	☆☆☆	☆☆☆	☆☆☆	☆☆☆
FLUENT	☆☆☆	☆☆	☆☆☆	☆☆☆
CFDesign	☆	☆	NE	☆
Fire,SWIFT,FAME	☆☆	☆☆	☆☆	☆☆
FIDAP,ICEM CFD	☆☆☆	☆	☆☆	NE
CFD++	☆☆☆	☆☆	NE	NE
Esperanza	NE	☆☆	☆☆	NE
STAR-CD,Pro*am	NE	☆☆	NE	NE
Vectis	NE	☆☆☆	NE	NE
PAM-FLOW	☆	NE	NE	NE

NE: No Entry / * Bad - Good *** /









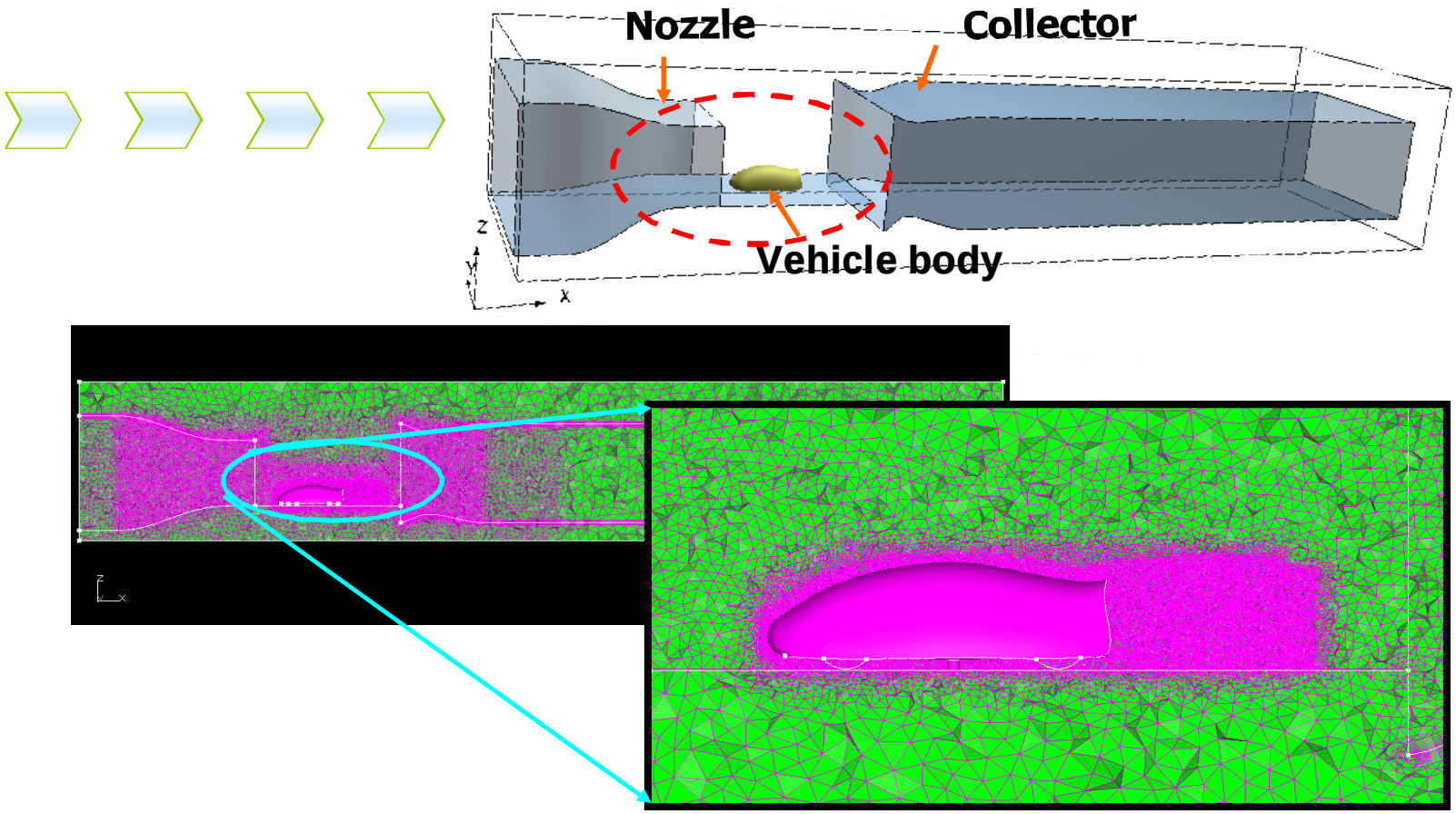
[Reference 1] JSAE Symposium No.14-01 “Comparison of CFD Commercial Codes and Computers - Benchmark CFD Study of Aero- dynamic, Engine Cold Flow, and Air-Conditioning-” (2001)
[Reference 2] Taniguchi, N., “Validation of CFD Commercial Codes for Vehicle Design and Development“ (2002) Paper Engine Number: 2002-01-1297

Characteristics of SC/Tetra

❑ Outstanding Computation Speed and Accuracy

Comparison of Commercial CFD software (2006)

* JSAE symposium on Recent Activities in CFD toward Higher Quality, No. 08-06 (2006)



Characteristics of SC/Tetra

❑ Outstanding Computation Speed and Accuracy

	C_D	C_L
Experiments	0.245	-0.273
Simulation	0.247	-0.275
Difference	<1%	<1%

[Reference 1] Kumano, T. Et al., Wind Tunnel Testing of a 1/5 Scale Vehicle Model (in Japanese), JSAE symposium on Recent Activities in CFD toward Higher Quality, No. 08-06 (2006).
(Japanese Title: 低C(D)車デザイン模型に基づくCFDベンチマーク)

[Reference 2] Shimano, K. Et al., Wind Tunnel Testing of JSAE Standard Low- aerodynamic-drag Vehicle Body Using 1/5 Scale Model, Review of Automotive Engineering, Vol. 30, No.1, (2009).

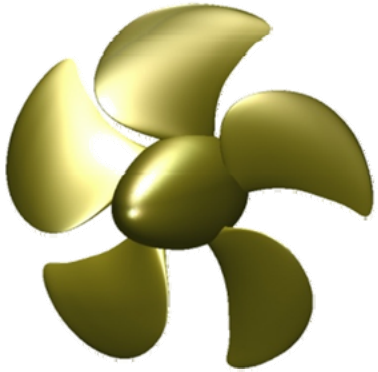
3. Propeller Cavitation Analysis (1)

Cavitation analysis of PPTC using CFD

*PPTC: Potsdam Propeller Test Case

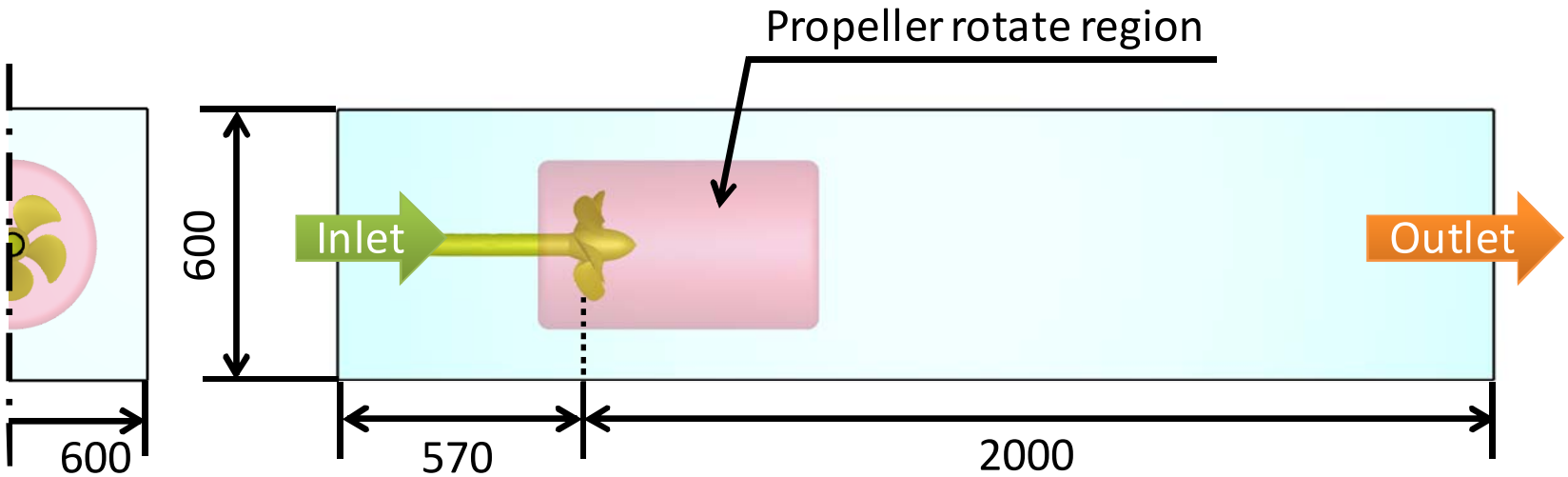
– Model propeller (Experimental conditions)

Diameter:	250 mm
Rotation speed:	25 rps
Velocity:	6.365・7.927・8.805 m/s



– Cavitation model

- Full cavitation model (Singhal et al, 2002)



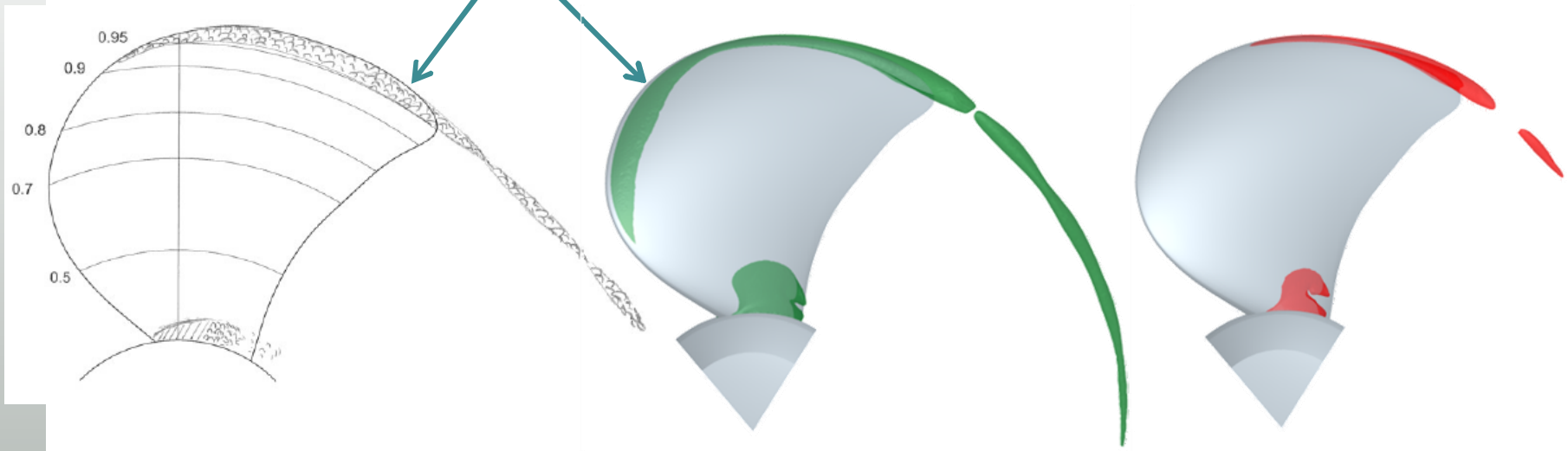
3. Propeller Cavitation Analysis (6)

Comparison of analysis and experimental results

- J = 1.019 (Velocity = 6.365 m/s) σ = 2.024

K_T (Thrust coefficient)
Exp : 0.3725
Cal : 0.3750 (+0.67%)

Cavity region

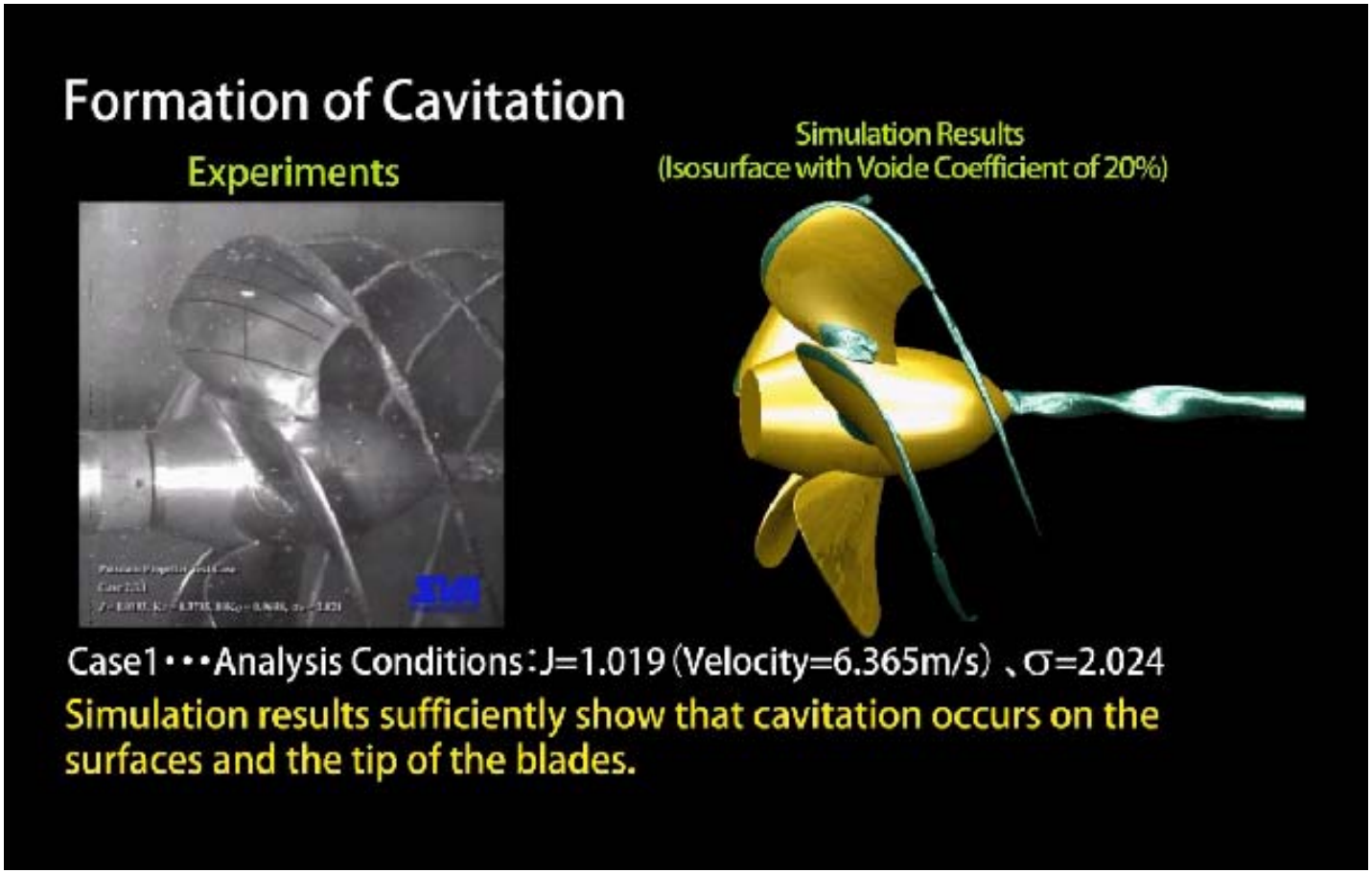


Sketch (Experimental) **Void fraction: 20%** **Void fraction: 50%**

Fujiyama1, K., Kim, C., Hitomi, D., (2011), Performance and Cavitation Evaluation of Marine Propeller using Numerical Simulations. Second International Symposium on Marine Propulsors (smp"11), Hamburg, Germany.

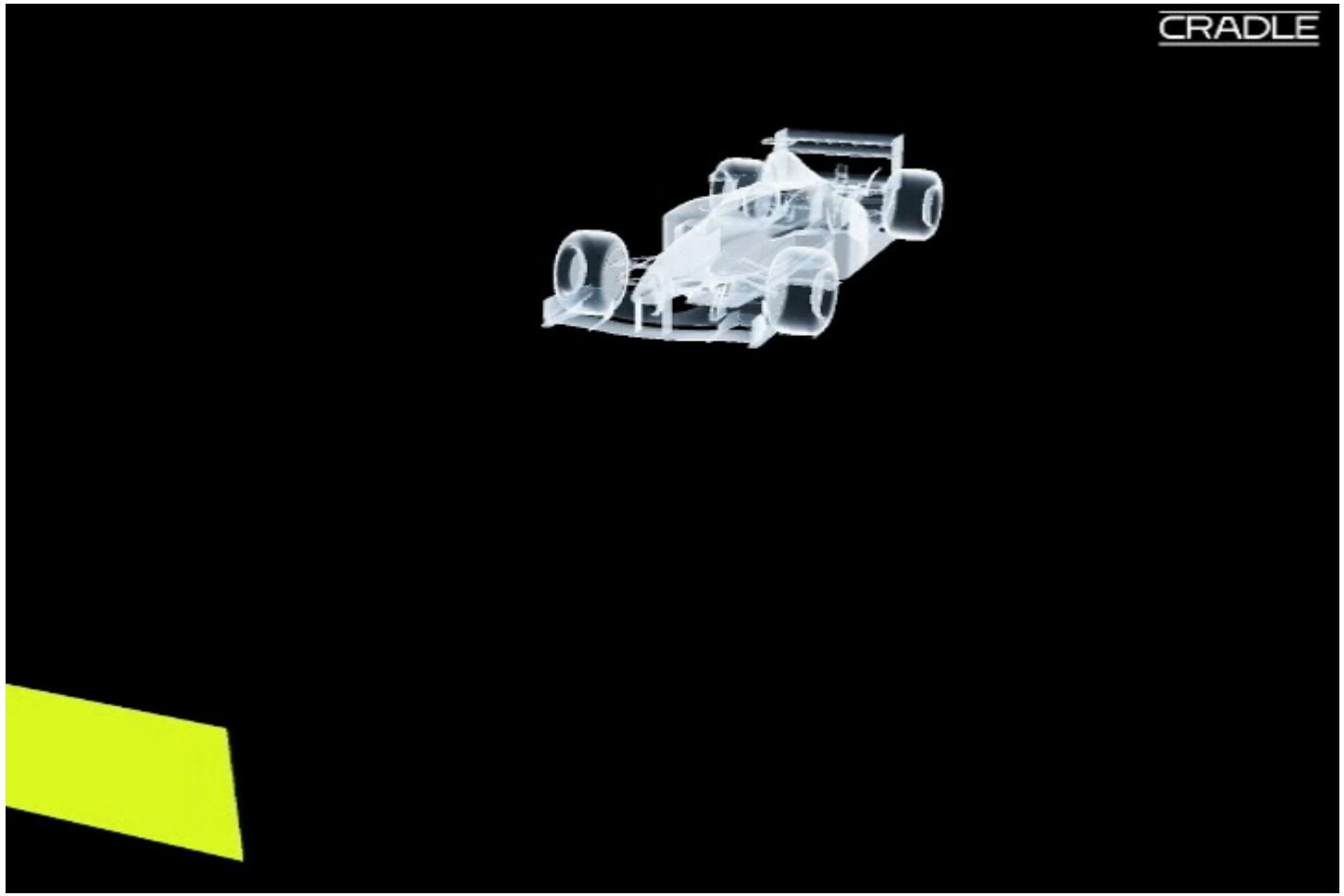
Outstanding Computation Accuracy

Propeller simulation including cavitation



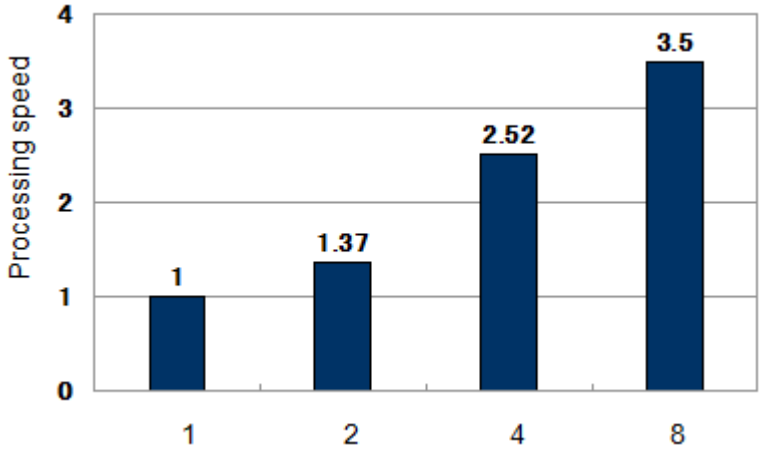
Experiment by
SVA Potsdam

State of the art Postprocessor

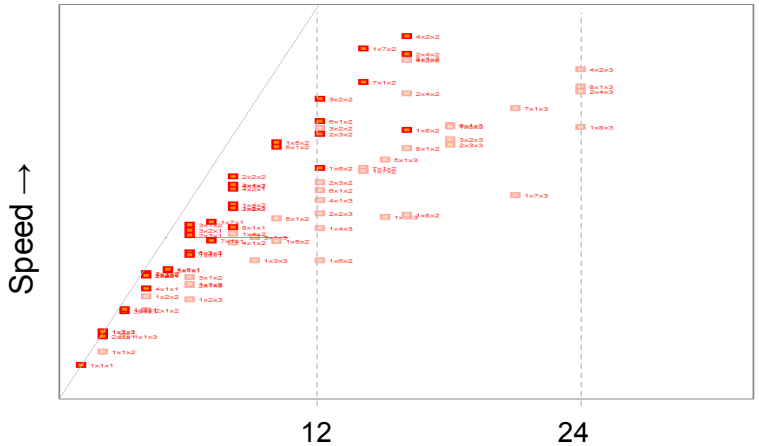


All Parallel Compatible (Pre/Solve/Post)

Meshing with Preprocessor



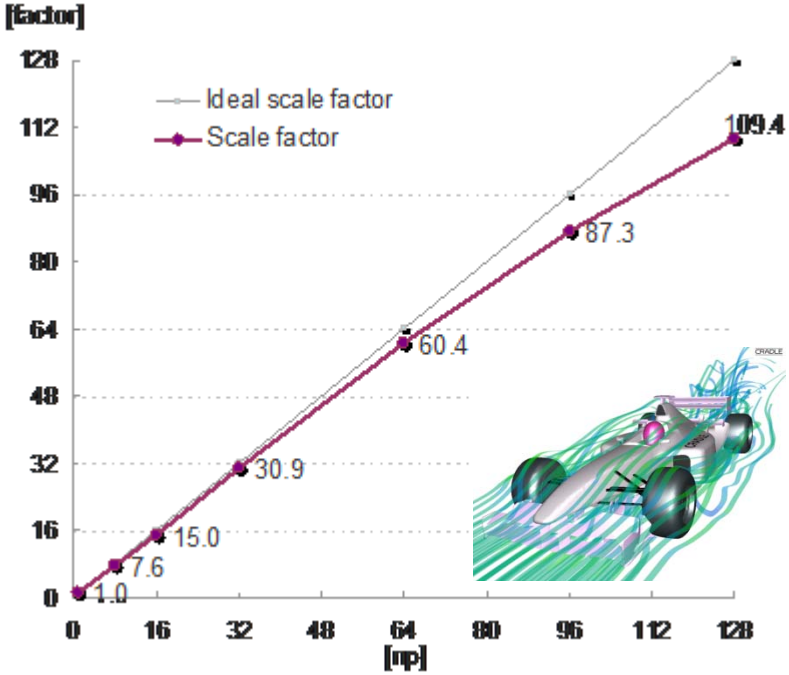
Drawing with Postprocessor



Calculation with Solver

Formula car
(30 mil. elements, flow only)

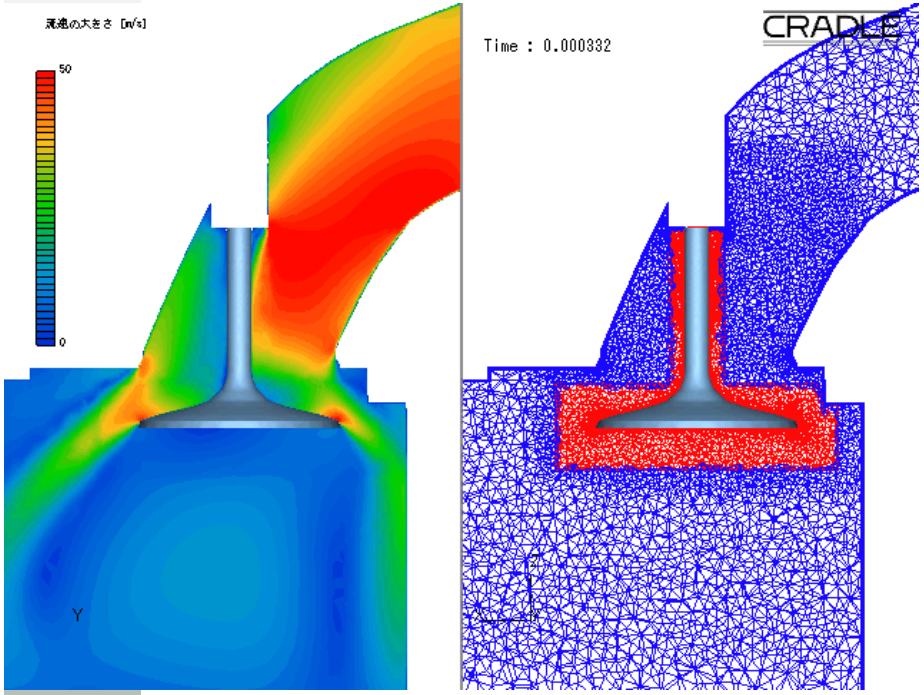
CPU: Xeon 5130(2GHz, 2core) x 2 x 32nodes
OS: Red Hat 5.2
Interconnect: Infiniband (DDR/SDR)

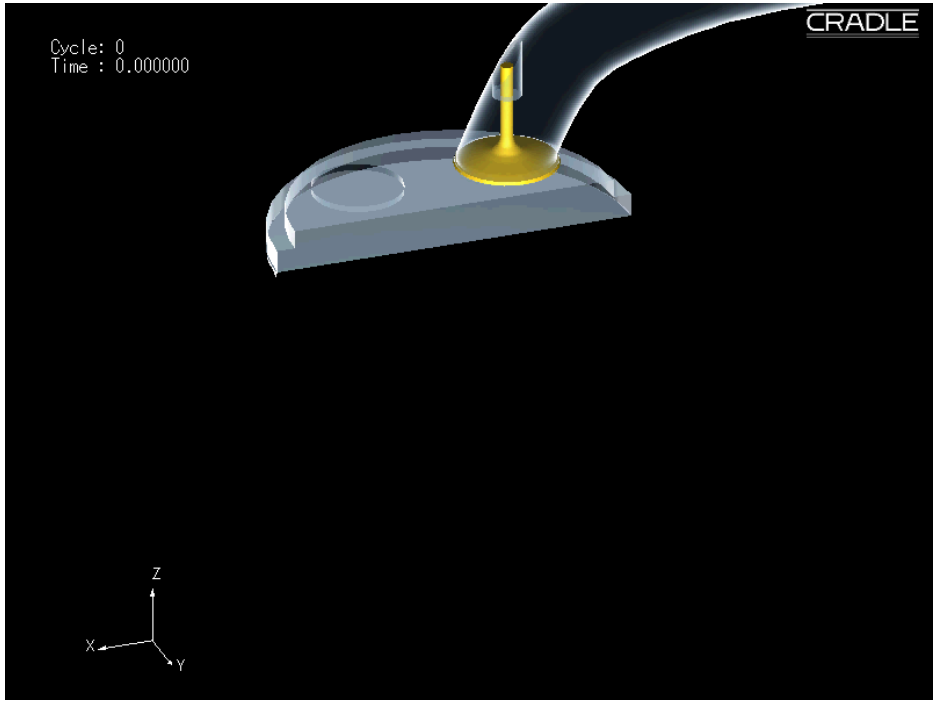


Unique and Advanced Features of SC/Tetra

Advanced Motion Handling

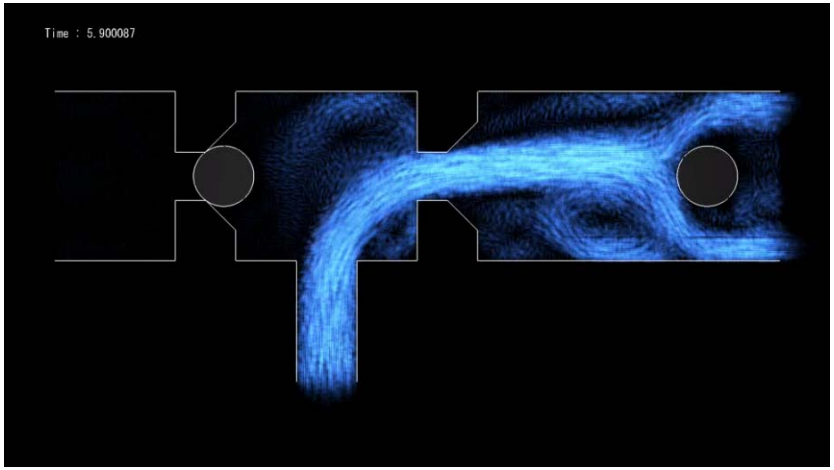
ALE / Passive Motion / Overset Mesh

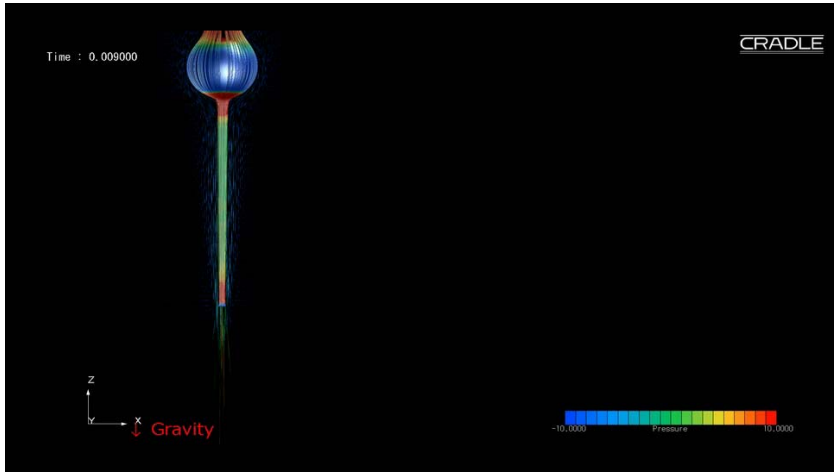


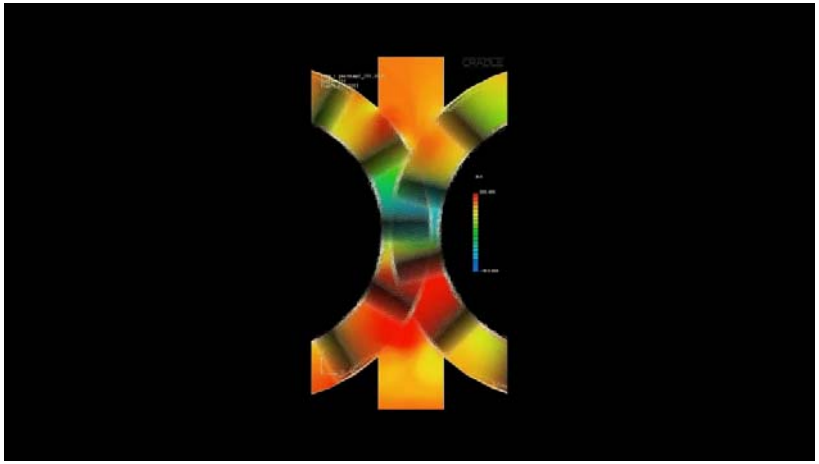


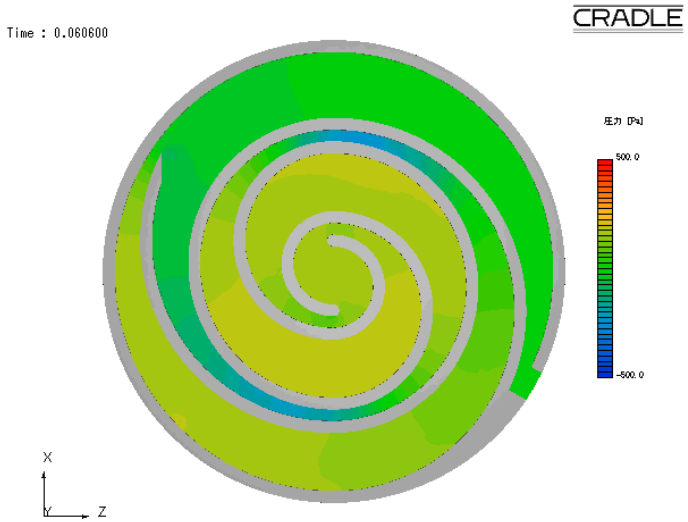
Advanced Motion Handling

ALE / Passive Motion / Overset Mesh



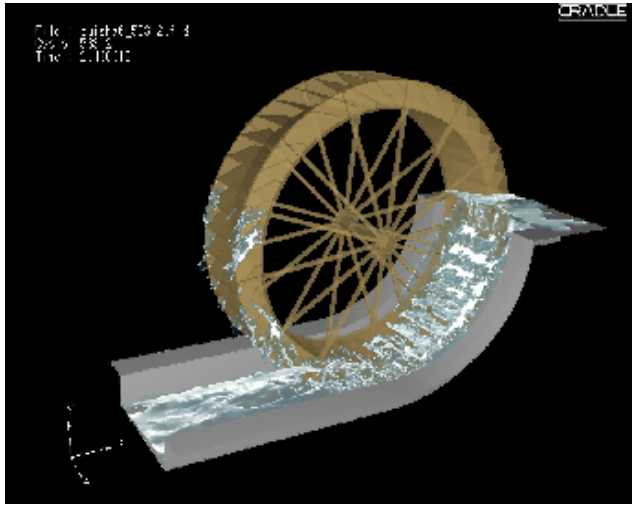


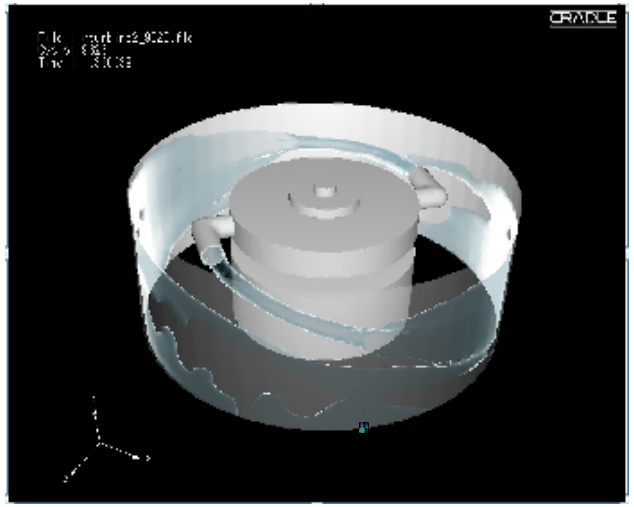


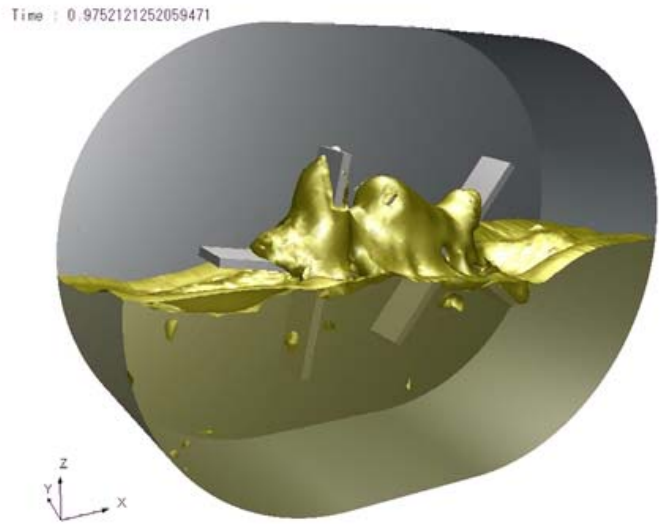


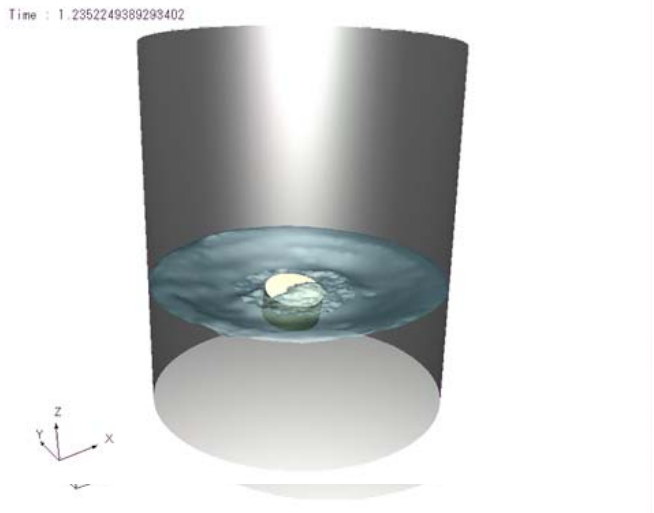
Advanced motion handling

VOF method with ALE and induced motion







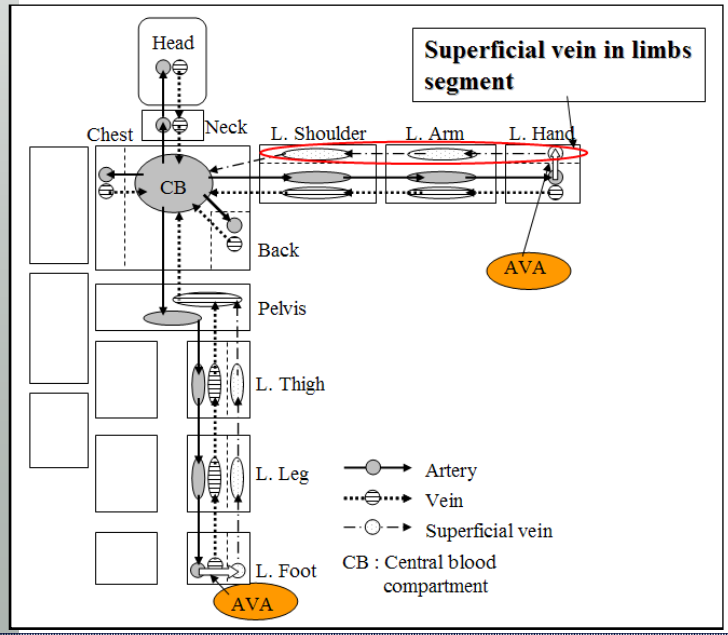


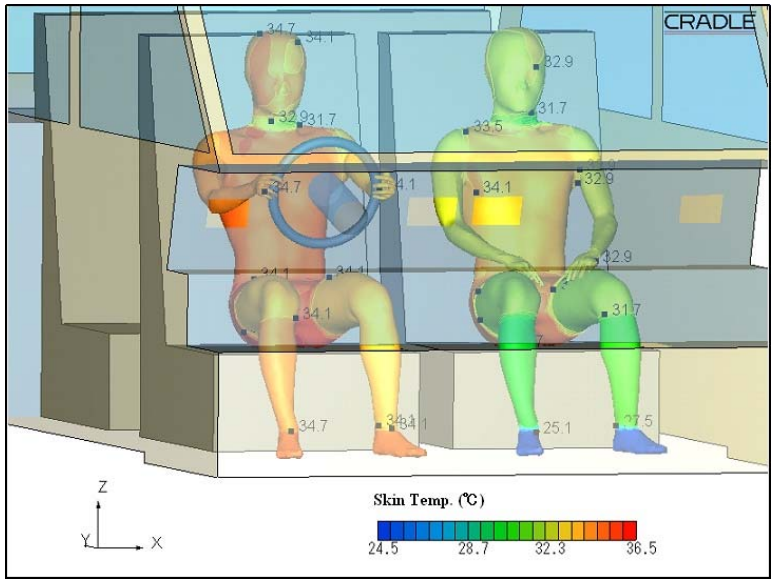
Thermoregulation model - *JOS*

The temperature and the amount of perspiration of human body can be simulated with MOST ADVANCED THERMOREGULATORY MODEL.

Heat transfer by detailed vascular system and heat generation by physiological factors of human body can be predicted with the consideration of morphological characteristics of an individual.

The human body is divided by segments and the heat balance equations of those segments are solved to predict the body temperature and the amount of perspiration.

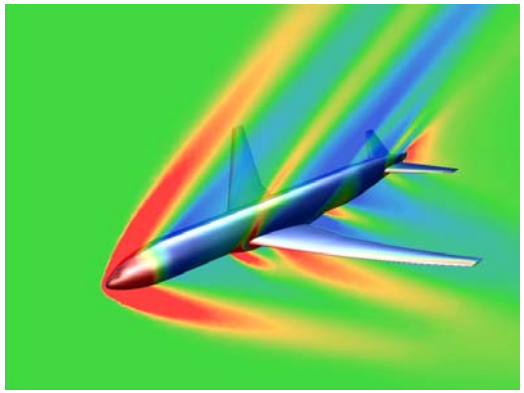




Density-Based Solver

- Numerical analysis method

Red : Default



  - Time marching method
    - 1st-order Euler method,
    - 2nd-order Runge-Kutta method,
    - Dual time stepping method (BDF2)
  - Approximate Riemann solver
    - Roe method,
    - HLL method,
    - Rotated-RHLL Flux method *1
  - Advection term
    - 2nd-order (Limiter function of Venkatakrishnan is applied)
  - Diffusion term
    - Alpha-damping scheme *2

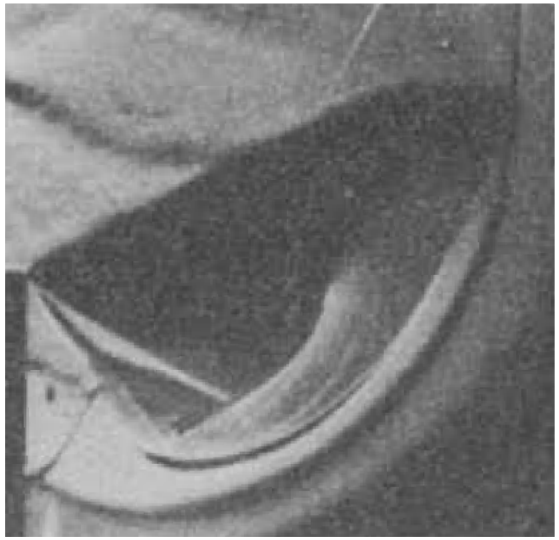
Reference

[1] Nishikawa, H. and Kitamura, K., \Very Simple, Carbuncle-Free, Boundary-Layer Resolving, Rotated-Hybrid Riemann Solvers," Journal of Computational Physics, Vol. 227, 2007, pp. 2560-2581.

[2] Nishikawa, H. Beyond Interface Gradient: A General Principle for Constructing Diffusion Schemes. AIAA2010-5093

Density-Based Solver

- Computational example of inviscid flow analysis
  - Validation example 15: “Shock Wave Diffraction”
  - Analysis overview
    - Supersonic flow analysis considering shock wave propagation (Ms=5.09)
  - Simulation results : Compared to the visible image of experiment
    - Experiment, Schlieren photograph[1]
    - Computational results, density gradient (animation)

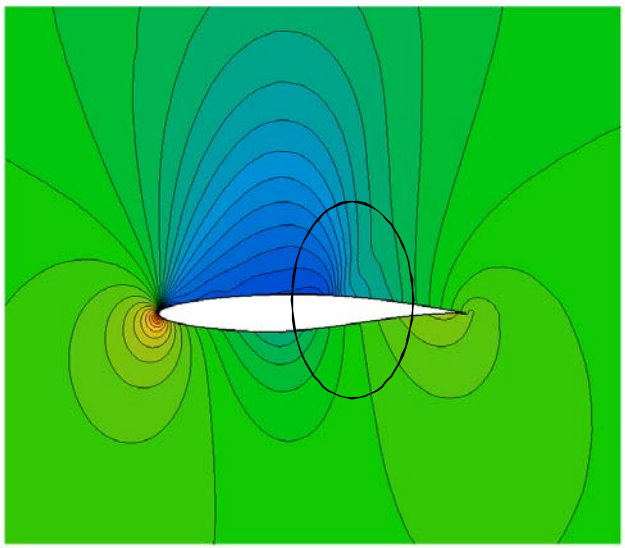


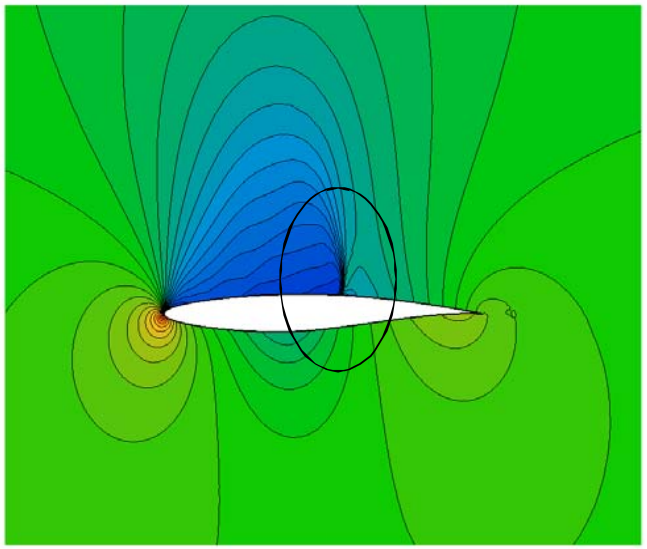
Reference

[1] Bazhenova, T. V.; Gvozdeva, L. G.; Nettleton, M. A. Unsteady interactions of shock waves. Prog. Aerospace Sci., 1984, 21(4), p. 249-331.

Density-Based Solver

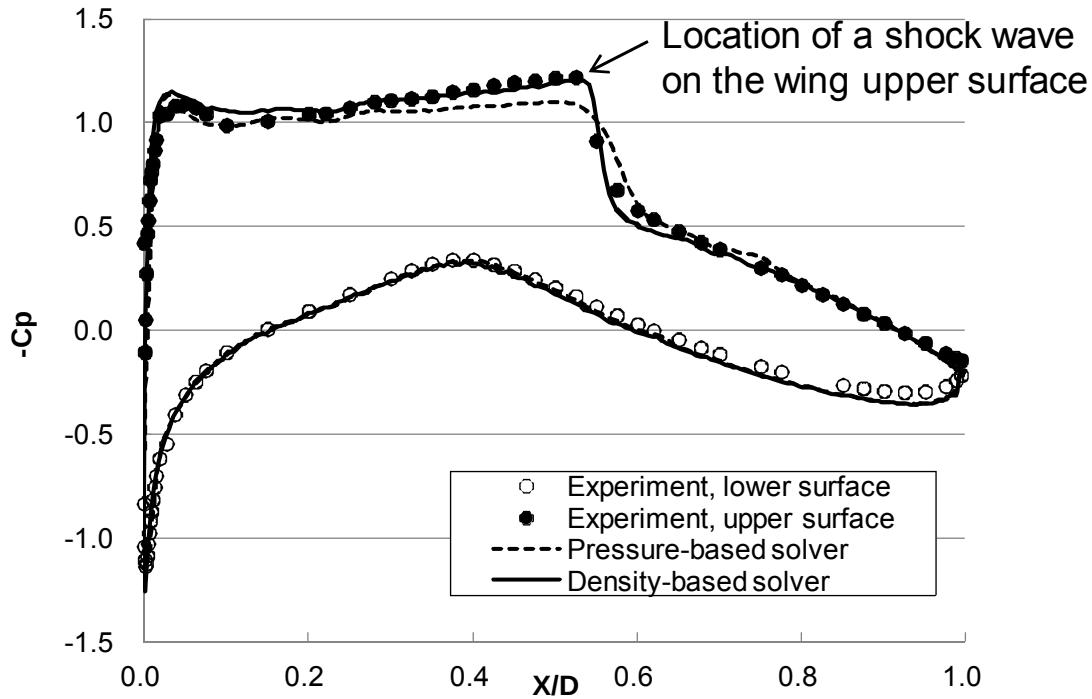
- Computational example of a viscous, turbulent flow analysis
  - Validation example 16: “Simulation of Flow with a Shock Wave around a Two-Dimensional Airfoil”
    - Analysis overview
      - Transonic flow analysis: Main stream Mach number of 0.729 is flowing over RAE2822 airfoil at 2.31° angle of attack. Reynolds number is 6.5×10^6.
      - Turbulent flow with SST k-ω model
    - Simulation results: Pressure distribution
      - Pressure-based solver
      - Density-based solver





Density-Based Solver

- Computational example of viscous and turbulent flow analysis
  - Validation example 16: "Simulation of Flow with a Shock Wave around a Two-Dimensional Airfoil"
    - Simulation results: Comparison of pressure coefficient with experiment[1]



Reference

[1] Cook, P. H. et al. Aerofoil RAE 2822 - Pressure Distributions, and Boundary Layer and Wake Measurements. AGARD Report AR 138. 1979.

Data Import

Data Import

Model file formats

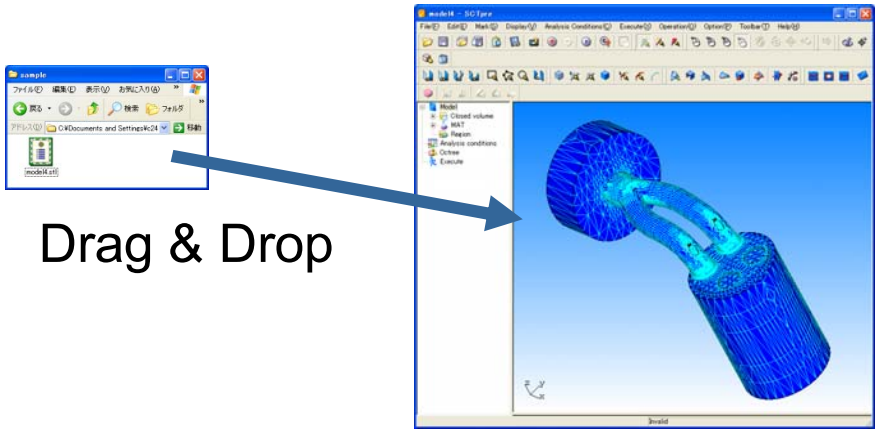
Parasolid XT	*.x_t
STEP	*.stp, .step
STL	*.stl
NASTRAN	*.nas
DXF	*.dxf
IGES	* .iges, .igs
ACIS(SAT)	* .sat
VDAFS	* .vda
UNIVERSAL	*.unv
ABAQUS	*.inp

Native file formats

CATIA V4	* .model, .session, .exp
CATIA V5	* .catpart, .catproduct
PRO/E, Creo	* .asm, .prt
Inventor	* .ipt, .iam
SolidWorks	* .sldprt, .sldasm
NX	* .prt
SolidEdge	* .par

Mesh file formats

NASTRAN	*.nas
ANSYS	*.cdb
UNIVERSAL	*.unv
ABAQUS	*.inp
Design Space	*.dat



Drag & Drop

Coupling Analysis

Coupling Analysis

- Structural Analysis

  SCT Structure, ANSYS(.cdb), ABAQUS(.inp), NASTRAN(.nas), I-DEAS(.unv)

  **** 2-way FSI: Direct coupling with Abaqus***

- Acoustic Analysis

  LMS SYSNOISE / Virtual.Lab

  Actraran

- Optimization

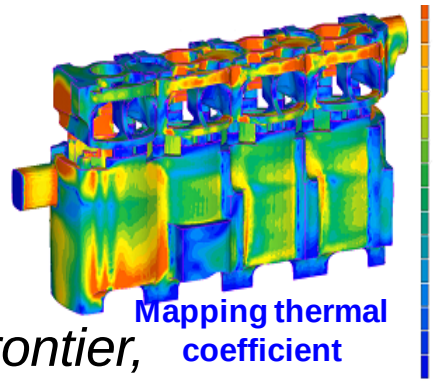
  HyperStudy, Optimus, iSIGHT, *modeFrontier,*

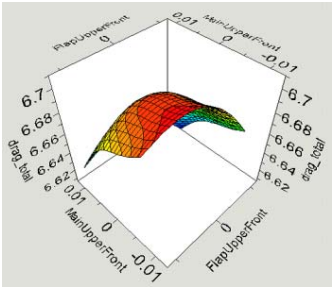
- Morphing

  HyperMesh, Sculptor, MeshWorks Morpher,

- 1D Simulation

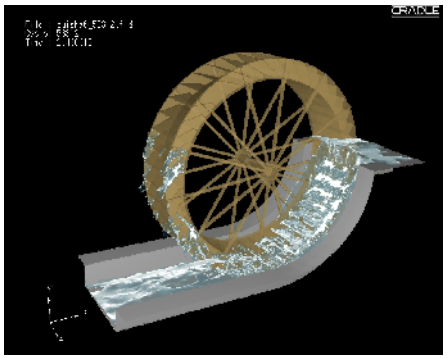
  Flowmaster, KULI

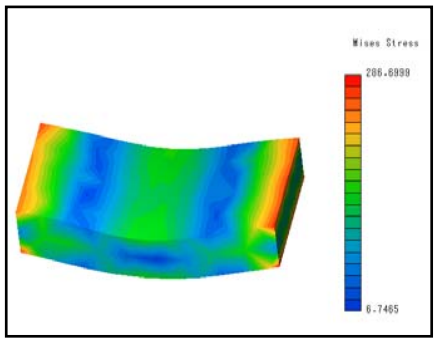


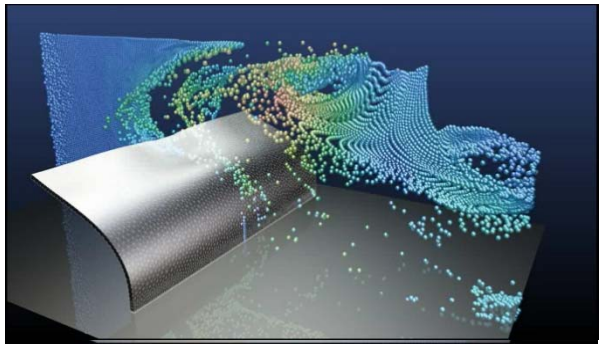


Fluid Structure Interaction

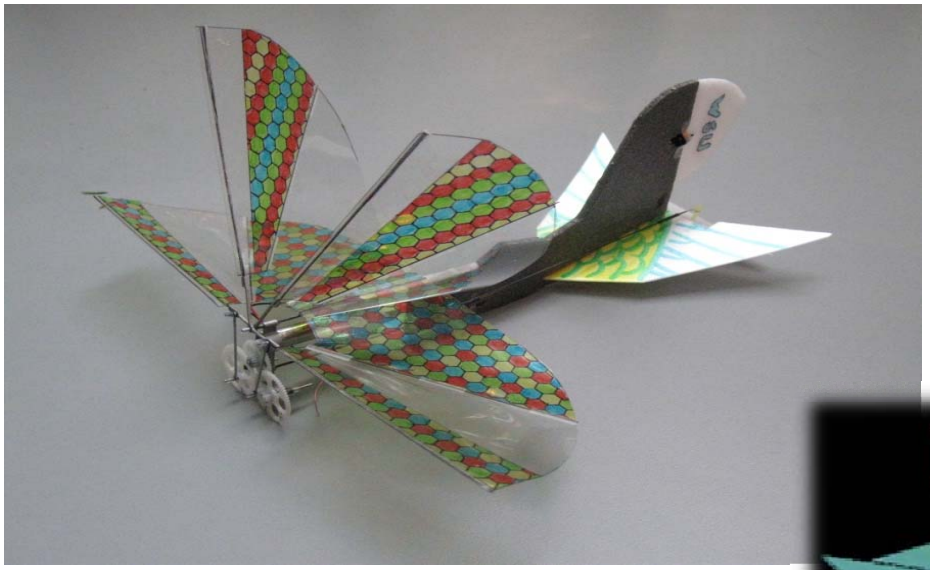
- 3 Kinds of FSI approaches
  - Motion of a rigid body driven by fluid force
    - SC/Tetra alone can simulate it using Dynamical ALE
  - 1-Way FSI: Stress in an object can be simulated by using pressure load or thermal values from CFD simulation
    - ***SC/Tetra Structure*** can be coupled
    - 3rd Party structural analysis can be coupled using Cradle's mapping tool
  - 2-Way FSI: Transient
    - Abaqus can be coupled

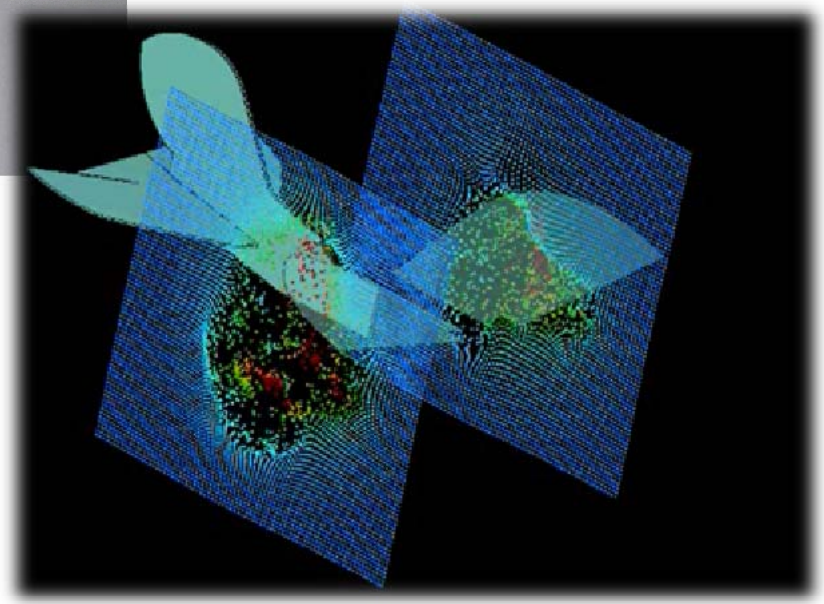






FSI Coupling Analysis: Direct coupling with Abaqus

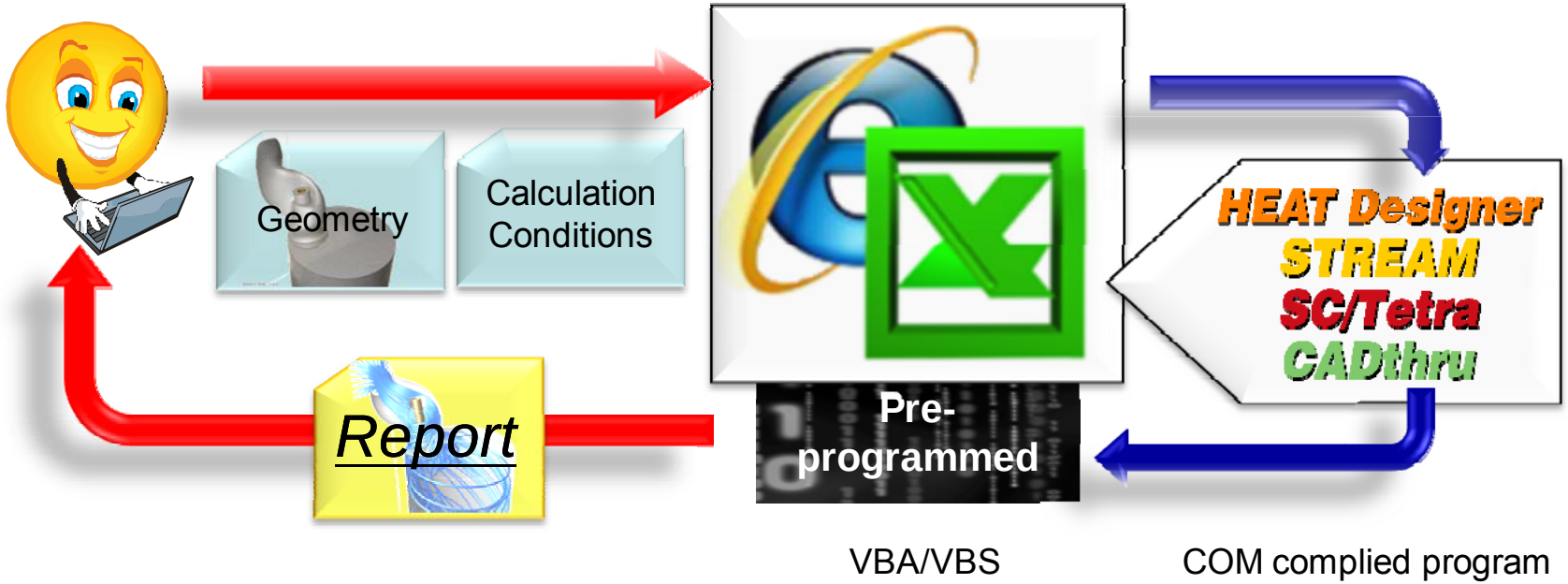




Automation

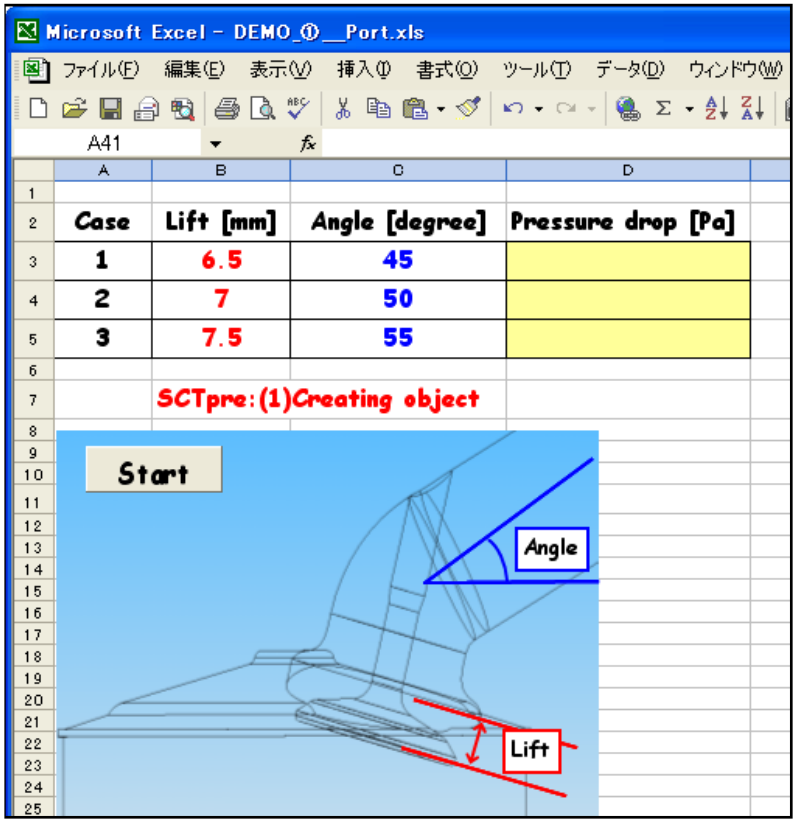
Customization & automation with VBA* & VBS*

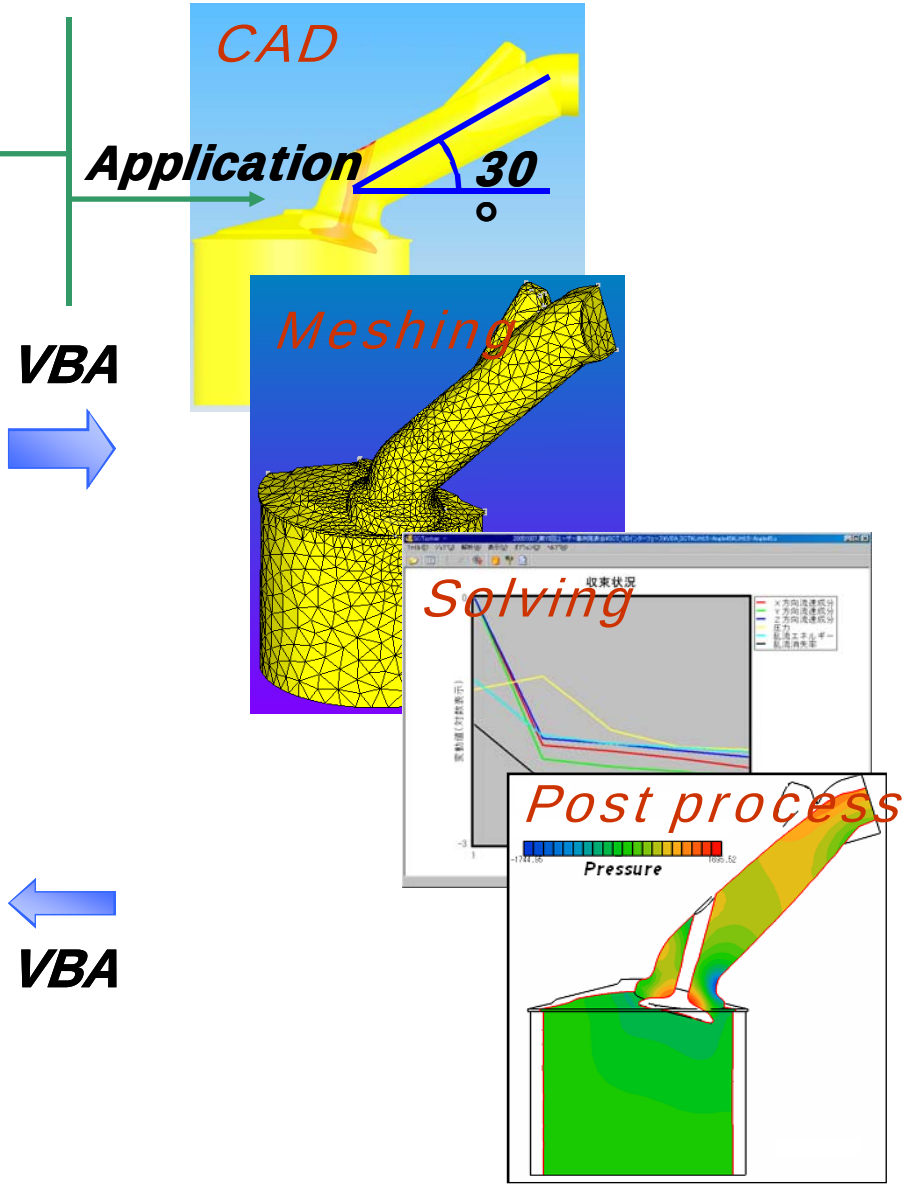
- Microsoft COM (Component Object Model) technology
  - Enables software components to communicate one another
  - Cradle products are all complied with COM technology
- Automation with VBA* & VBS* (thereafter, called VBI)
  - *VBA: Visual Basic for Applications, Microsoft's event-driven programming language to enhance functions of MS Office products.
  - *VBS: Visual Basic Script, Microsoft's active scripting language used in Microsoft Windows and Internet Information Server. (WSH, IE)



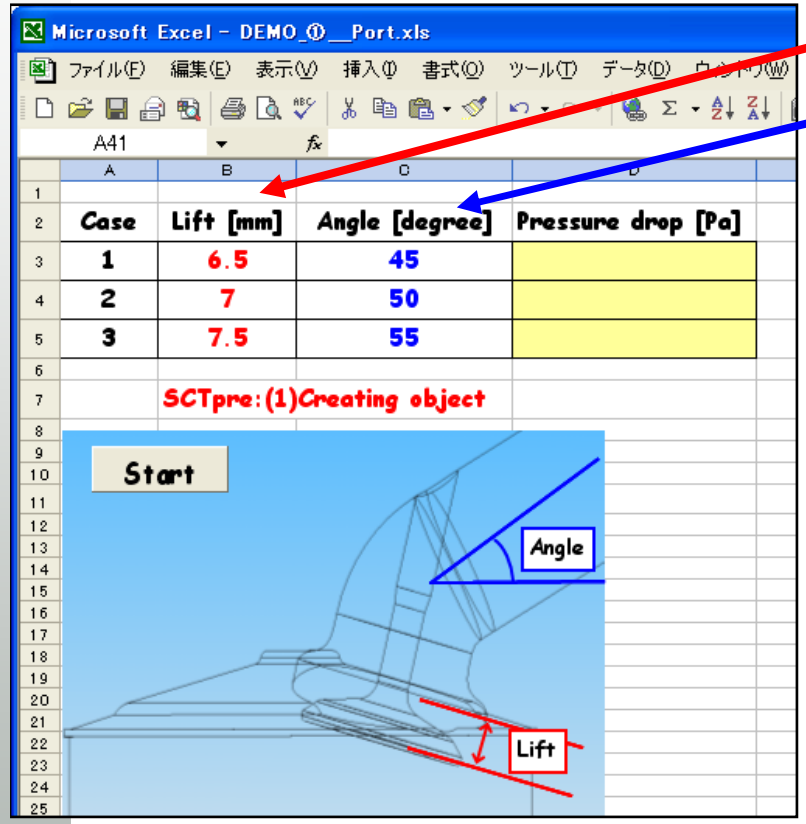
Fully Automated System

COM driven





Fully Automated System



An user defines:

- LIFT
- ANGLE

Automatically modifies models according the parameters, executes computations, obtains pressure drop, and creates a report.

Excel

↓

SolidWorks

↓

CADthru

↓

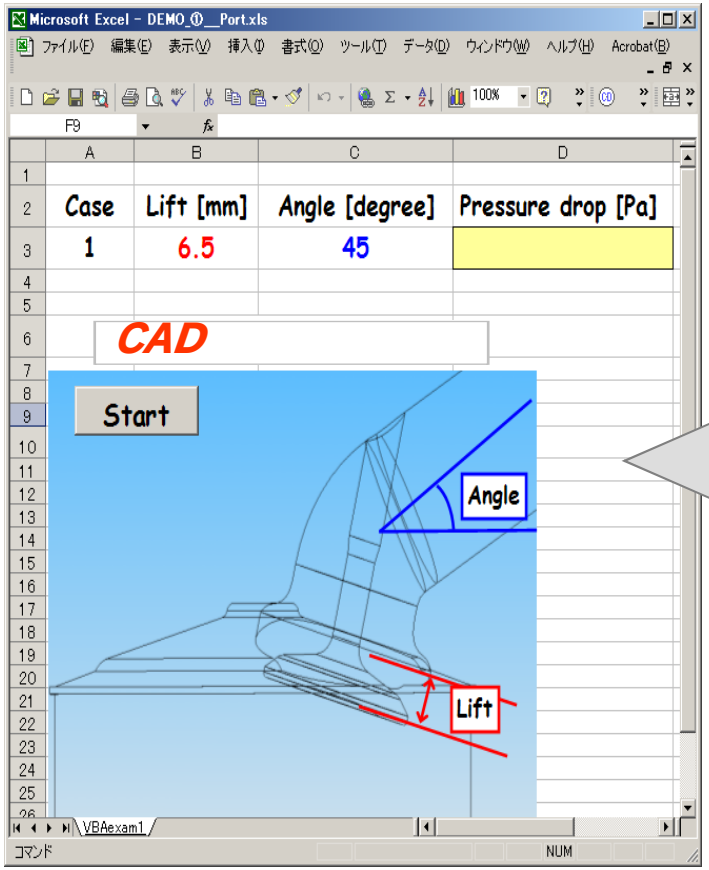
SC/Tetra

↓

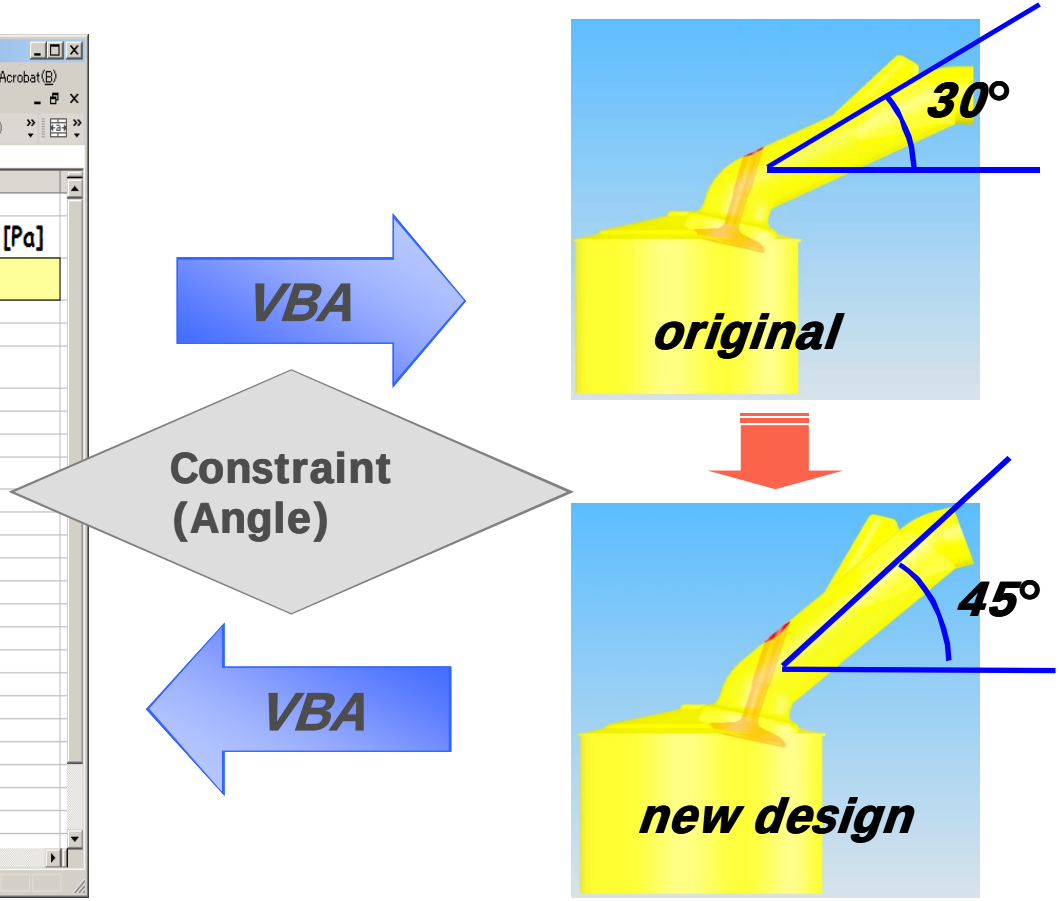
Report

Fully Automated System

User : EXCEL

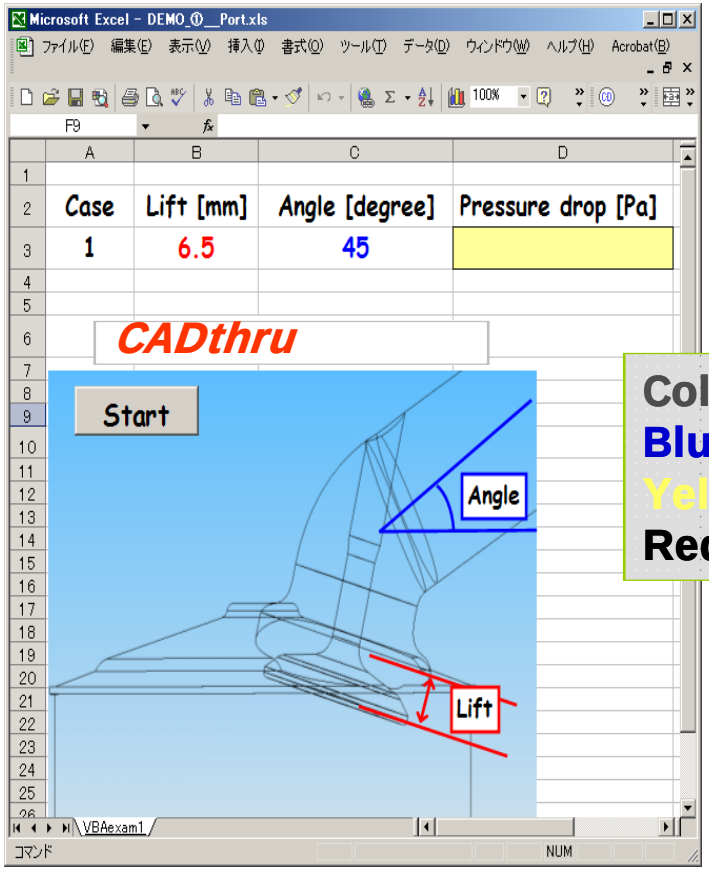


Application : CAD

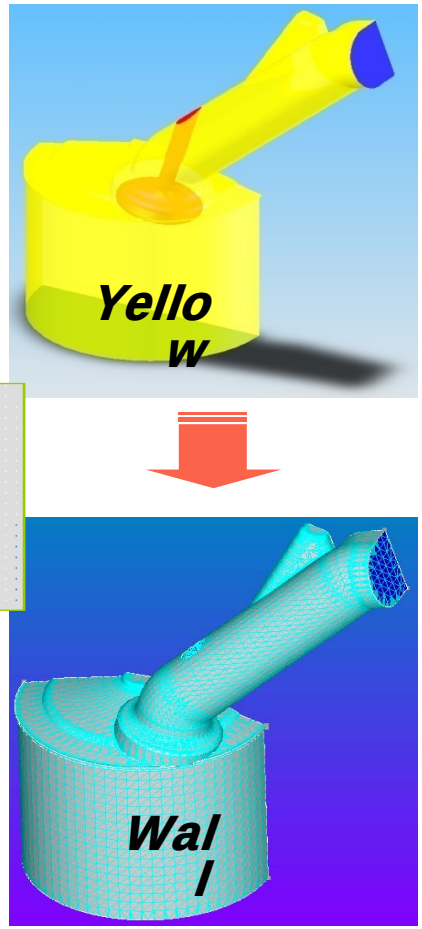


Fully Automated System

User : EXCEL



Application : CADthru



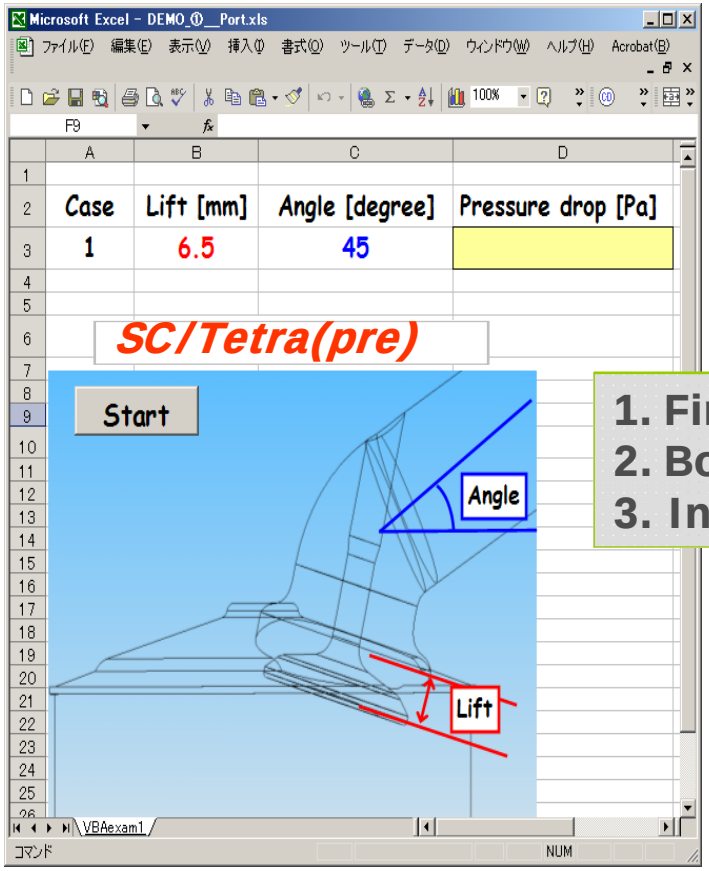
VBA

Color-Region Table
Blue:Inlet
Yellow:Wall
Red:Valve

VBA

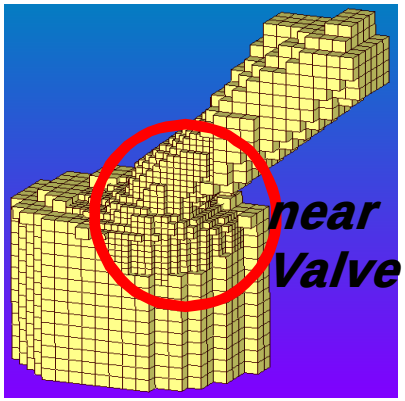
Fully Automated System

User : EXCEL

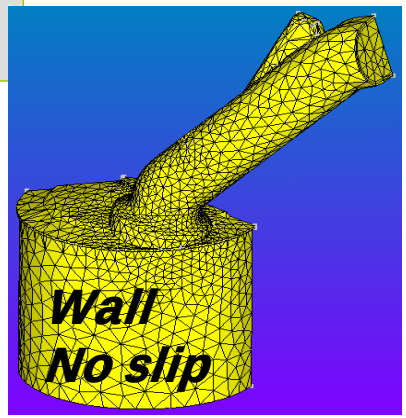


Application : SC/Tetra

VBA



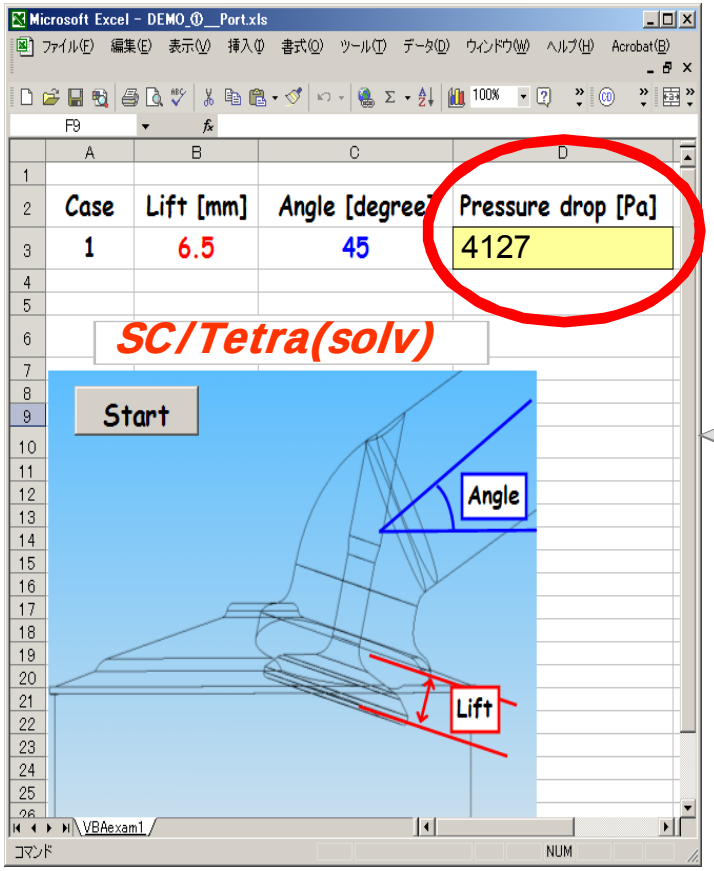
1. Fine mesh near Valve
2. Boundary layer on Wall
3. Intet:Flux Wall:No slip



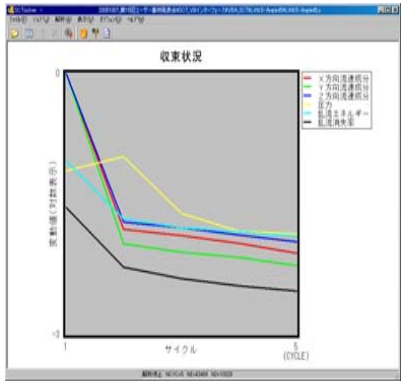
VBA

Fully Automated System

User : EXCEL



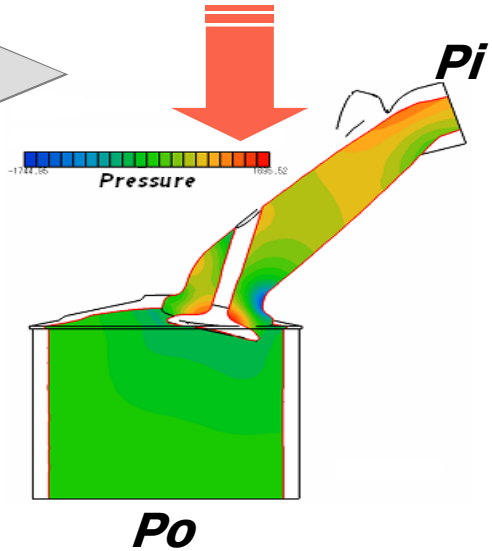
Application : SC/Tetra



VBA

1.Execution
2.Get Pi-Po

VBA



Thank you!