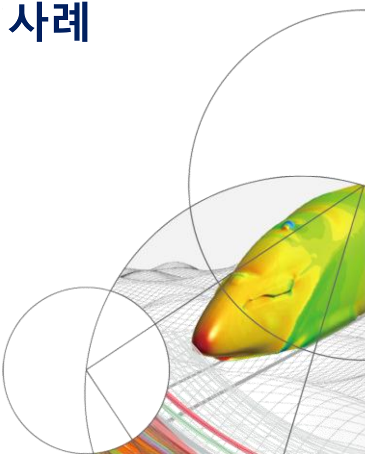
넥스트폼 OpenFOAM 활용 사례

2015. 09. 10
4th OKUCC
넥스트폼 김 병 윤



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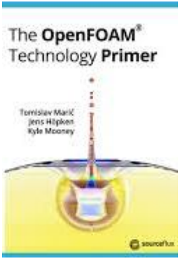
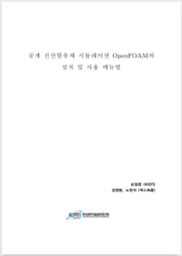
  - 유체기계
  - HVAC
  - 압축성
  - dynamicMesh
  - 열유동
  - 다상유동

OpenFOAM 사용자환경 개발

개발 배경

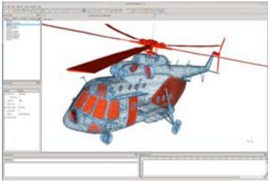
- OpenFOAM의 아쉬운 점
  - OS
    - CFDSupport, BlueCFD, SymScape
  - Install
    - OpenFOAM in box of CFDSupport
  - **GUI**
    - **IconCFD, Helyx-Os, Caedium**
  - Documentation
    - CoCoons Project, sourceflux, KISTI
  - Language

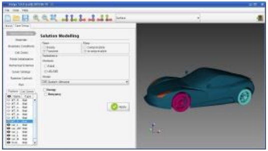


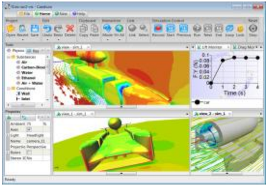


GUI 선행 사례

- IconCFD
  - iconCFD : Modularized package
    - process, wrap, mesh, cold, thermal, optimize, VOF
  - FOAMpro : 개발 중단
- Engys
  - Helyx
  - Helyx-OS
- Symscape
  - Caedium : RANS flow, Panel flow, Builder, Transient, exchange, viz export

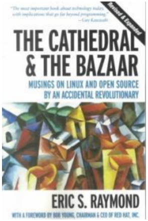






개발 전략

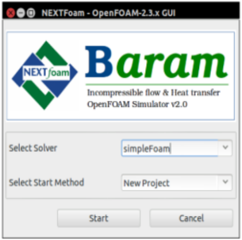
- OpenFOAM의 성공 비결



- **제품이 아닌 플랫폼**
  - OpenFOAM 기본 구조에 충실
  - Source code open
  - Solver별로 별도 구성
  - Documentation
  - Graphic → paraview

Baram

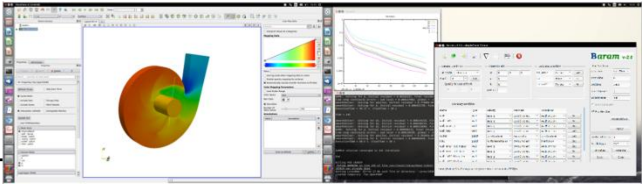
- 넥스트폼이 개발한 OpenFOAM GUI
  - GNU GPL
  - OpenFOAM-2.3.x 기반
  - pyFoam, swak4Foam, Gnuplot, paraview 사용
  - Language : Python 2.7, pygtk
  - OS : 리눅스



- Release
  - Baram-v1.0 : 2015.05.11
  - Baram-v1.0.1 : 2015.06.16
  - Baram-v2.0-beta : soon

Baram

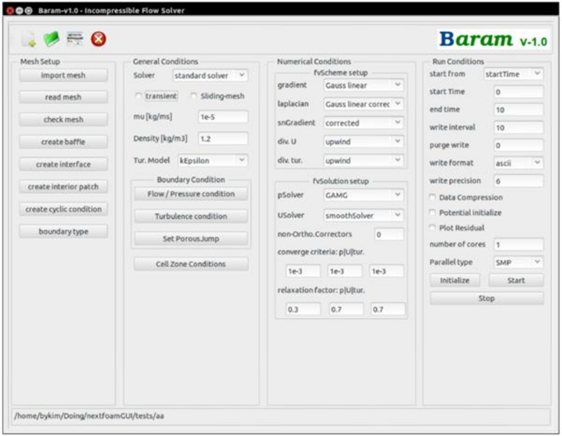
- New OpenFOAM code
  - Solver : simplNFoam, pimpleNFoam
  - Turbulence model
    - modified k-epsilon series, SST k-omega model
    - Modified epsilon wall function, nut wall function
  - Boundary condition
    - porousJumpPressure, viscosityRatioDissipationRateInlet
  - Matrix solver : modified PBiCG, smoothsolver
  - Utilities : changeBCs

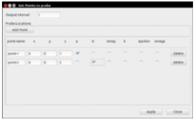


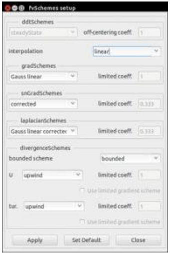
Baram의 기능

- Solver
  - Incompressible flow, heat transfer
- Turbulence
  - k-epsilon series, k-omega series, Spalart-Allmaras, laminar, inviscid
- Mesh
  - Convert(msh, cas, ccm) / Read OF mesh
  - Check, scale, translate, change patch type, create baffle, create interface, create cyclic condition, create interior
- Cell zone
  - MRF, Sliding mesh, Porous, Source(momentum, energy), fixed Value(U, T)
- 후처리
  - Force report, probe location, patch integrate, patch average, monitoring, flow rate...

Baram-v1.0 GUI 환경

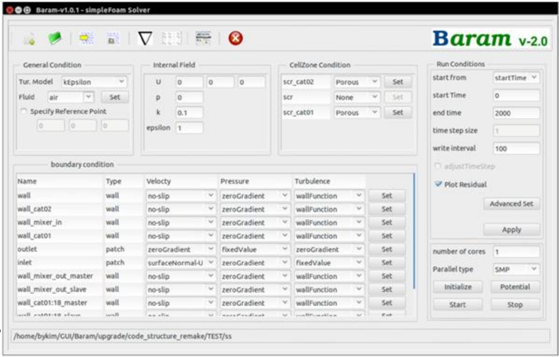




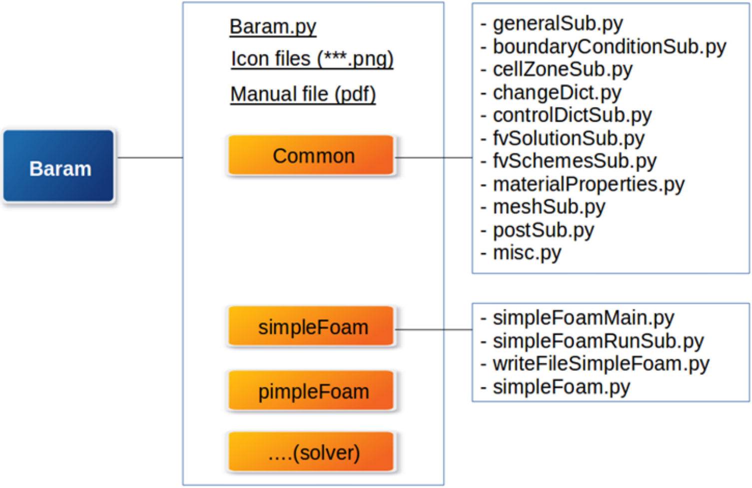


Baram-v2.0-beta

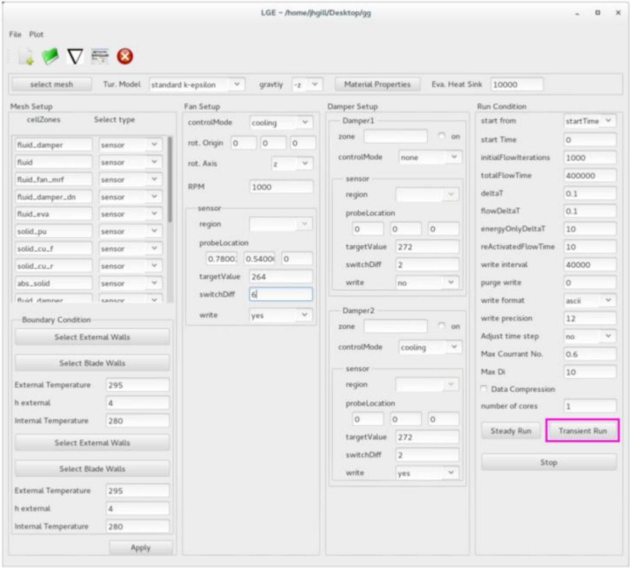
- 화면 구성 변경
- 코드 구조 변경 – solver 별로 관리
- 설정 범위 확대 – fvSolution, fvSchemes, BC
- Solver upgrade – simpleNFoam, pimpleNFoam
- Bug fix



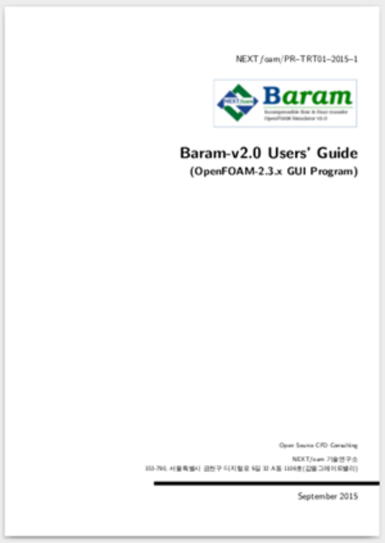
Baram-v2.0-beta 소스코드 구조



확장 사례


LGE – /home/jhgill/Desktop/gg
File
Plot
select mesh
Tur. Model
standard k-epsilon
gravtiy
-z
Material Properties
Eva. Heat Sink
10000
Mesh Setup
cellZones
Select type
fluid_damper
fluid
fluid_fan_mrf
fluid_damper_dn
fluid_eva
solid_pu
solid_cu_f
solid_cu_r
abs_solid
sensor
Boundary Condition
Select External Walls
Select Blade Walls
External Temperature
295
h external
4
Internal Temperature
280
Apply
Fan Setup
controlMode
cooling
rot. Origin
rot. Axis
z
RPM
1000
sensor
region
probeLocation
0.7800
0.5400
targetValue
264
switchDiff
6
write
yes
Damper Setup
Damper1
zone
on
controlMode
none
sensor
region
probeLocation
targetValue
272
switchDiff
2
write
no
Damper2
controlMode
cooling
write
yes
Run Condition
start from
startTime
start Time
0
initialFlowIterations
1000
totalFlowTime
400000
deltaT
0.1
flowDeltaT
0.1
energyOnlyDeltaT
10
reActivatedFlowTime
10
write interval
40000
purge write
0
write format
ascii
write precision
12
Adjust time step
no
Max Courrant No.
0.6
Max Di
10
Data Compression
number of cores
1
Steady Run
Transient Run
Stop

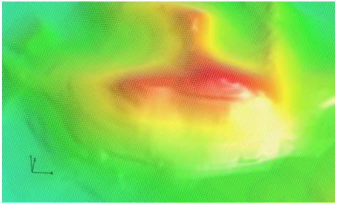
Baram - documentation



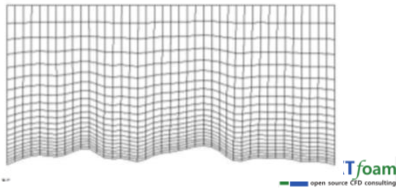
적용 사례

WindScape

- 대기경계층을 포함하는 대공간 유동 해석 문제
- OpenFOAM의 대기경계층 모델
  - atmBoundaryLayerInletVelocity
  - atmBoundaryLayerInletEpsilon
  - nutRoughWallFunction

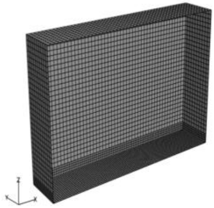


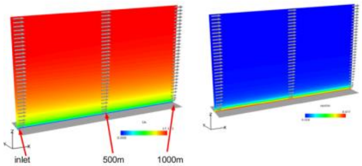
- 격자 생성
  - **DEM(GIS program) → plot3d surface mesh → 3d Hexahedral mesh(in-house code) → domain extensi**
- Solver : simpleFoam

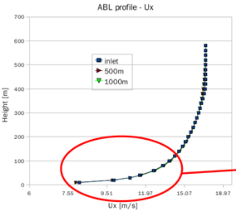


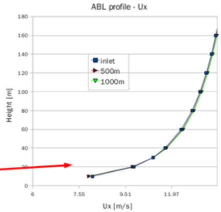
WindScape. 대기경계층 모델 검증

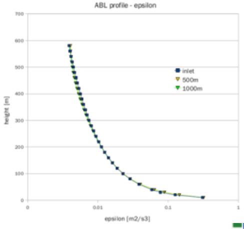
- 격자 : 1000x200x600m
  - 지면에서 10x10x10m
- 난류 모델 : kEpsilon, sigmaEps=1.1
- 경계조건
  - nutRoughWallFunction - Ks=9, Cs=0.327





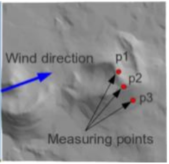


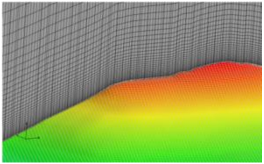


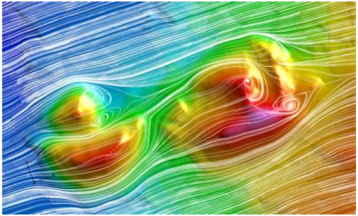


WindScape. 제주 새별 오름

- 격자
  - 지면격자 resolution : 5m
  - 1st cell height : 2m
  - 11,090,000 cells
- BC
  - AWS data. 2.9m/s, 250deg at 10m

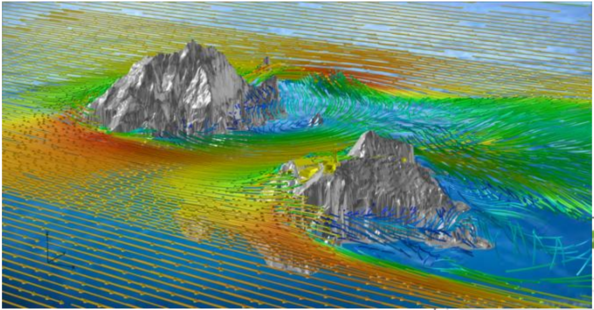




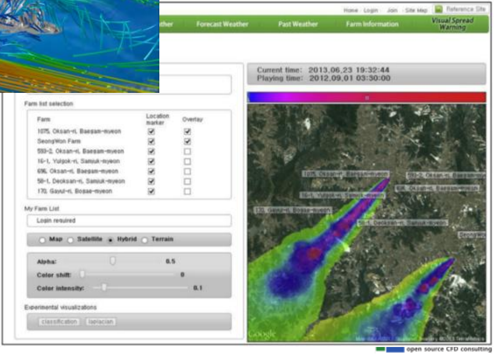


	계측	계산
P1	3.3m/s , 251º	3.5m/s , 247º
P2	4.9m/s , 249º	4.7m/s , 253º
p3	0.9m/s , 189º	3.8m/s , 246º

WindScape. 기타 해석 사례



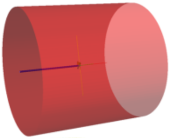
독도 주위 유동 해석

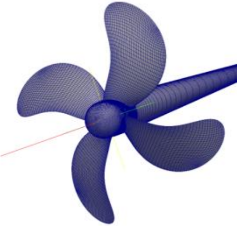


축산바이러스 확산 예측

- 유동 해석을 통한 DB 구축
- 실시간 스칼라 해석을 통한 바이러스 환산 예보

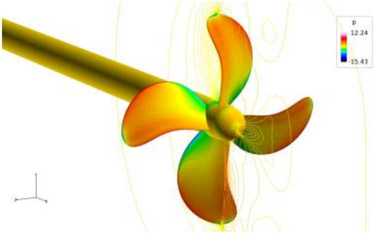
유체기계. 프로펠러 검증





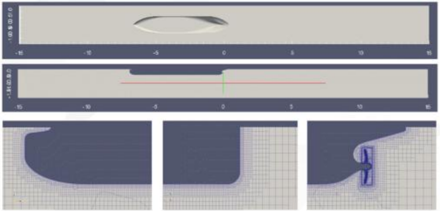
- 격자 : KRISO 제공(Pointwise, 2,451,953 hybrid)
- 조건 : KRISO 실험 조건(930rpm, 2.131m/s)
- Solver : simpleFoam, pimpleDyMFoam
- 난류모델 : realizableKE
- KRISO 실험 및 계산(FL)결과와 비교

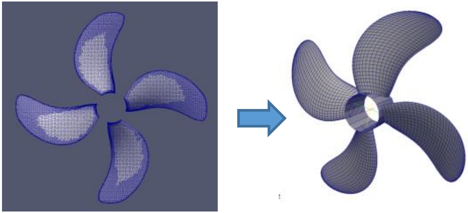
	T	Q	Error-T	Error-Q
실험	-140.14	4.728		
OF	-136.96	4.57	2.27%	3.34%
FL	-131.07	4.643	6.47%	1.80%

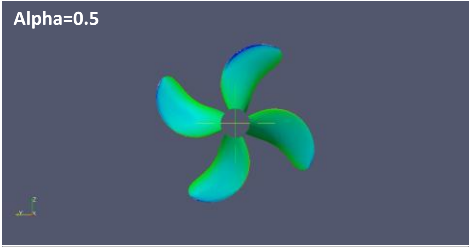


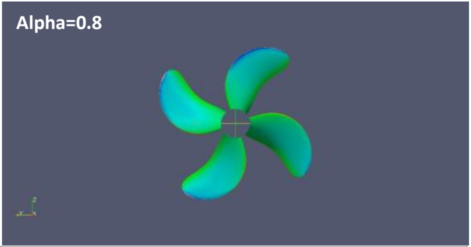
유체기계. hull + propeller + cavitation

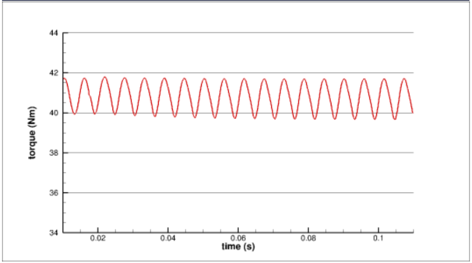
- snappyHexMesh
- Sliding mesh
- Cavitation model
- KRISO 실험 및 계산 결과와 비교
- **소음 해석 코드와 연동**
  - CFD 결과 BEM code input으로 mapping
  - 소음 계산

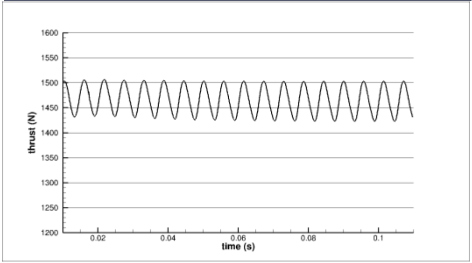


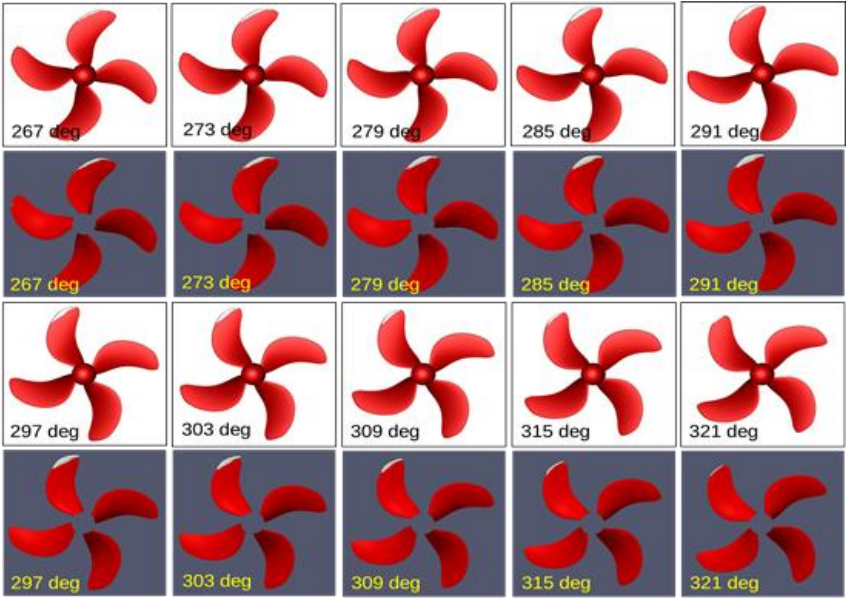



Alpha=0.5


Alpha=0.8

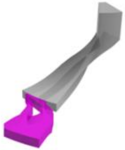

torque (Nm)
44
42
40
38
36
34
0.02
0.04
0.06
0.08
0.1
time (s)

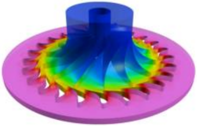

thrust (N)
1600
1550
1500
1450
1400
1350
1300
1250
1200
0.02
0.04
0.06
0.08
0.1
time (s)

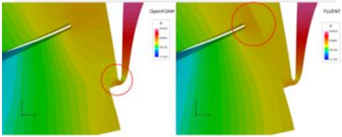

267 deg
273 deg
279 deg
285 deg
291 deg
267 deg
273 deg
279 deg
285 deg
291 deg
297 deg
303 deg
309 deg
315 deg
321 deg
297 deg
303 deg
309 deg
315 deg
321 deg

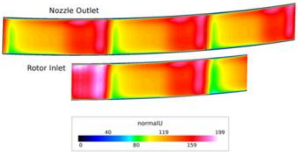
유체기계. 가스터빈

- Solver : densityBasedTurbo(MRF)
- 격자
  - turboGrid, snappyHexMesh
  - cyclicGgi, overlapGgi
- 작동조건
  - 40000rpm
  - Inlet : 3.91MPa, 1253K
  - Outlet : 1.38MPa
- Fluent 결과와 비교
  - Mass flow rate 0.49%
  - Torque : 1.01%
  - Outlet temperature : 0.51%







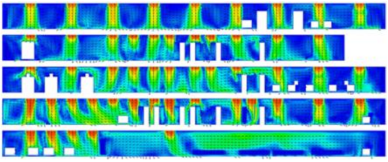


유체기계. 플런저 펌프

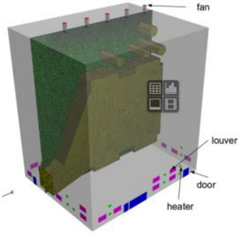
- Plunger 운동, cavitation
- Clearance 영향 포함
- 가시화실험 결과와 비교
- Solver
  - SNUFoam-cavitation 기반
  - Layering 기능 추가
  - solidBodyMotionFunction – translationTable 추가
  - ggi
  - tgridMeshToFoam

HVAC

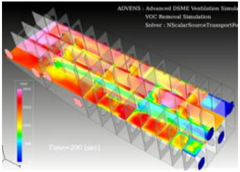
- Cell zone condition
  - Porous, MRF
  - Source(energy, momentum)
  - Fixed value(U, T)
    - pressureGradientExplicitSource
- airAgeFoam solver
- porousJumpPressure B.C.
- wallRadiationHeatFlux B.C.



클린룸



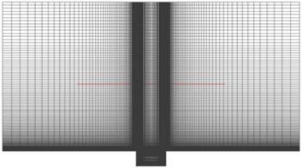
enclosure

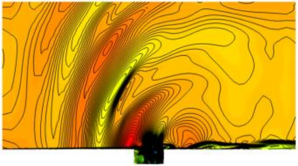


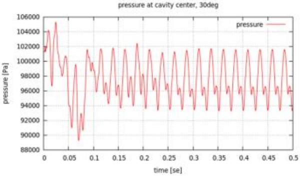
선박 블럭

압축성유동. 2D cavity

- Transonic cavity flow with injection
- M=0.6
- Mesh
  - **Matlab → plot3d → OpenFOAM**
- Solver : rhoPimpleFoam
- 난류 : SST k-omega
- 경계조건
  - Injection velocity M= M_{mean} +Asin(cωt)
    - **groovyBC**
  - **waveTransmissive** U, p

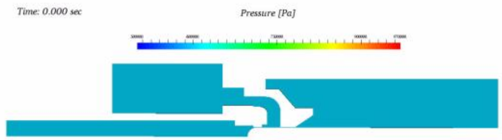






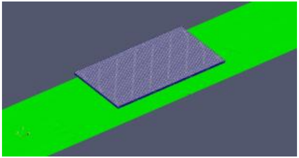
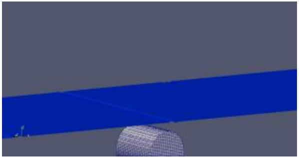
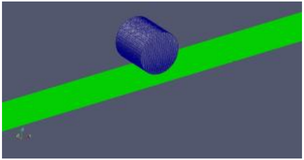
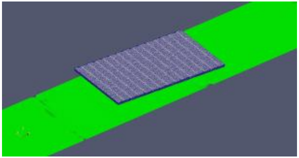
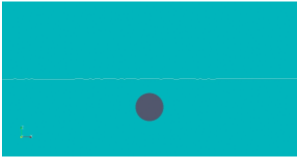
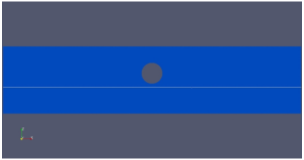
압축성유동. 차단기

- Modified rhoPimpleDyMFoam
- Dynamic mesh - Layering



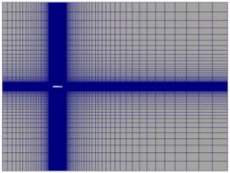
Dynamic mesh

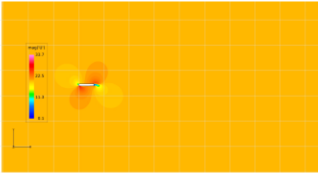
- Water Entry / Exit loading 추정
- waves2Foam을 이용한 조파 시뮬레이션

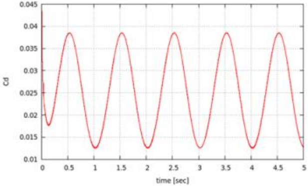







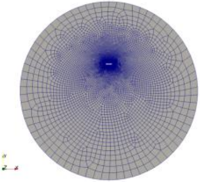
Dynamic mesh

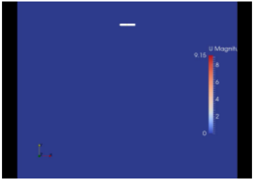
- PMM
- Rotating arm

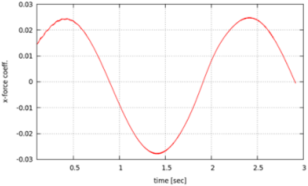










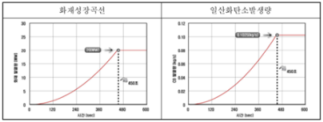


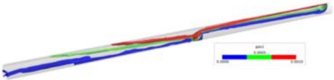
열유동. 냉장고

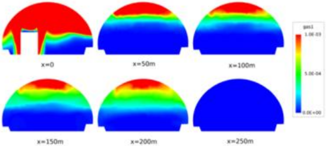
- 정상상태 / 비정상상태 복합열유동 해석
- 온도제어 알고리즘 구현
  - 센서 온도에 따라
  - Fan, evaporator, damper 제어
- 가변 시간 간격
- 선택적 방정식 풀이

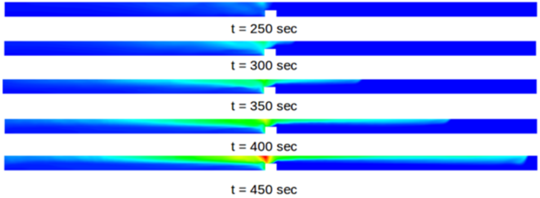
열유동. 터널 화재

- 부력이 포함된 열전달 및 연소가스 거동 해석
- 시간에 따른 에너지, 스칼라 소스
  - fvOption의 codedSource
- 솔버 : modified buoyantPimpleFoam
- 난류 : modified kEpsilon
  - 안정성 향상
  - 부력에 의한 난류 생성항 추가



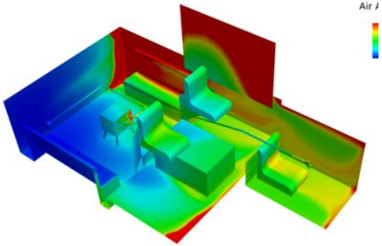


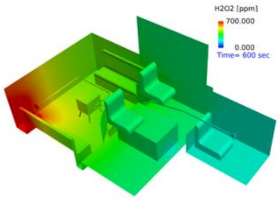


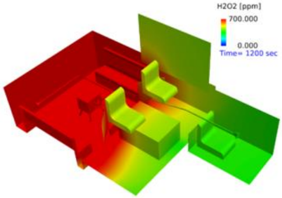


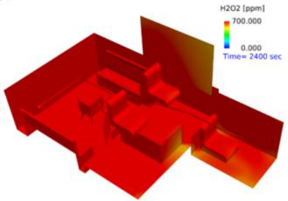
열유동. 제독현상 해석

- 비정상상태, 자연대류, 화학종
- 응축 현상 해석
  - Equilibrium vapor pressure 계산
  - 응축 개시 농도 계산
  - 응축량 계산
- 공기연령 계산



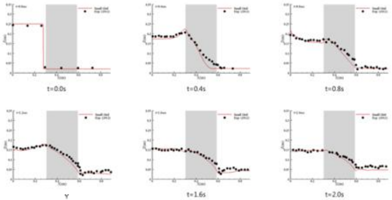


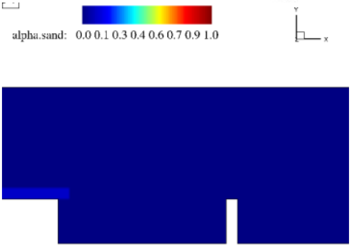


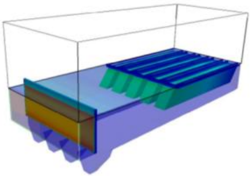


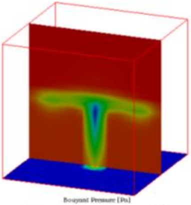
다상유동. 침전지

- VOF
  - interFoam + energy + boussinesq + particle + porous + passive scalar
- Eulerian
  - 물, 공기, 모래



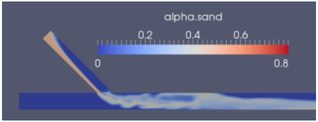




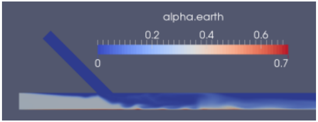


다상유동. 관중혼합

- 관중 액상제 / 입상제 혼합
- 물, 공기, 모래, 흙
- multiphaseEulerFoam



모래의 체적분율



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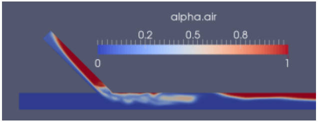
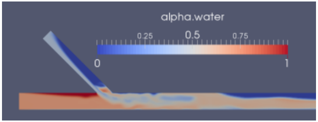


공기의 체적분율



물의 체적분율