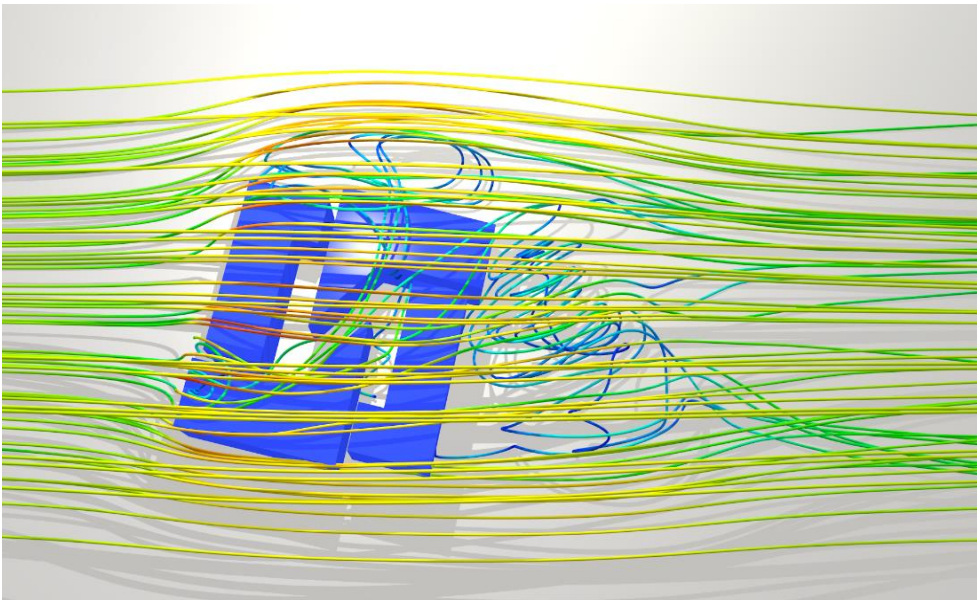


# BARAM-v6.3 upgrade



2021. 11. 11

(주)넥스트폼 김 병 윤

# 목차

- BARAM이란?
- History
- 개발 배경
- BARAM의 구조 / 개발 방법
- BARAM의 개발 방향
- BARAM v6.3의 기능
- 앞으로의 계획
- 마무리

# BARAM이란?

- 넥스트폼이 개발한 OpenFOAM® 기반의 CFD 패키지
- 공개소스 프로그램 GNU GPL



OpenFOAM

- The OpenFOAM Foundation

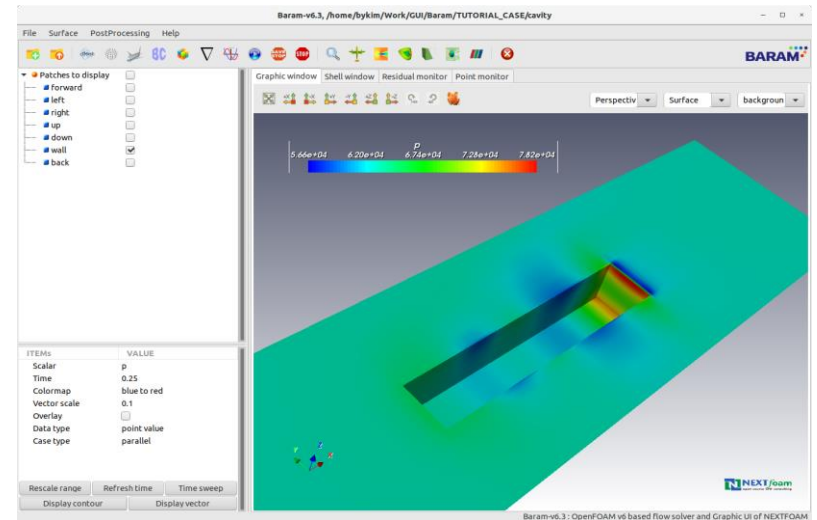
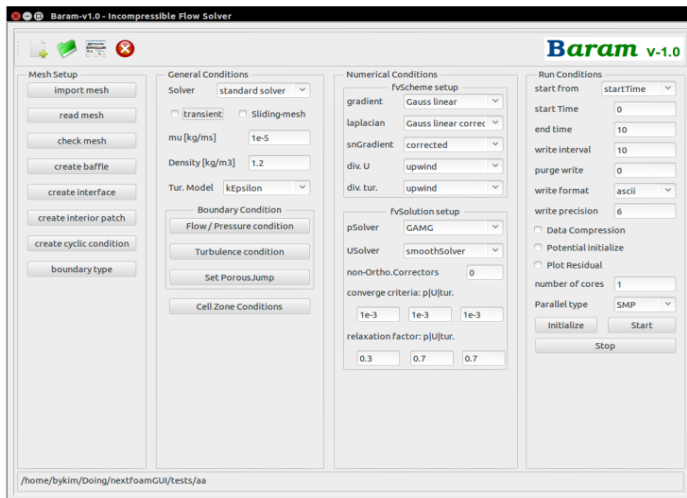
nextFoam6  
TSLAeroFoam

- 넥스트폼의 OpenFOAM 패키지
- Solver, Library, API

GUI

- Pre / post

# History



# 개발 배경

OpenFOAM의 부족한 점 보완

DIY CFD의 기본 프레임

공개 소스 패키지



OpenFOAM의 활성화

맞춤형 CFD의 확대

CFD의 대중화

# BARAM의 구조 / 개발 방법

## 솔버의 안정성/정확성

- 좋지 않은 격자에서 안정성/정확성 문제
- 초기조건에 민감한 문제

## 복잡한 사용방법

- 많은 파일에서 경계조건 설정
- 복잡한 수치해석 기법 설정
- 복잡한 데이터 추출 / 모니터링 방법

## 불편한 사용자환경

- Text User Interface
- 익숙하지 않은 OS, 파일 편집기

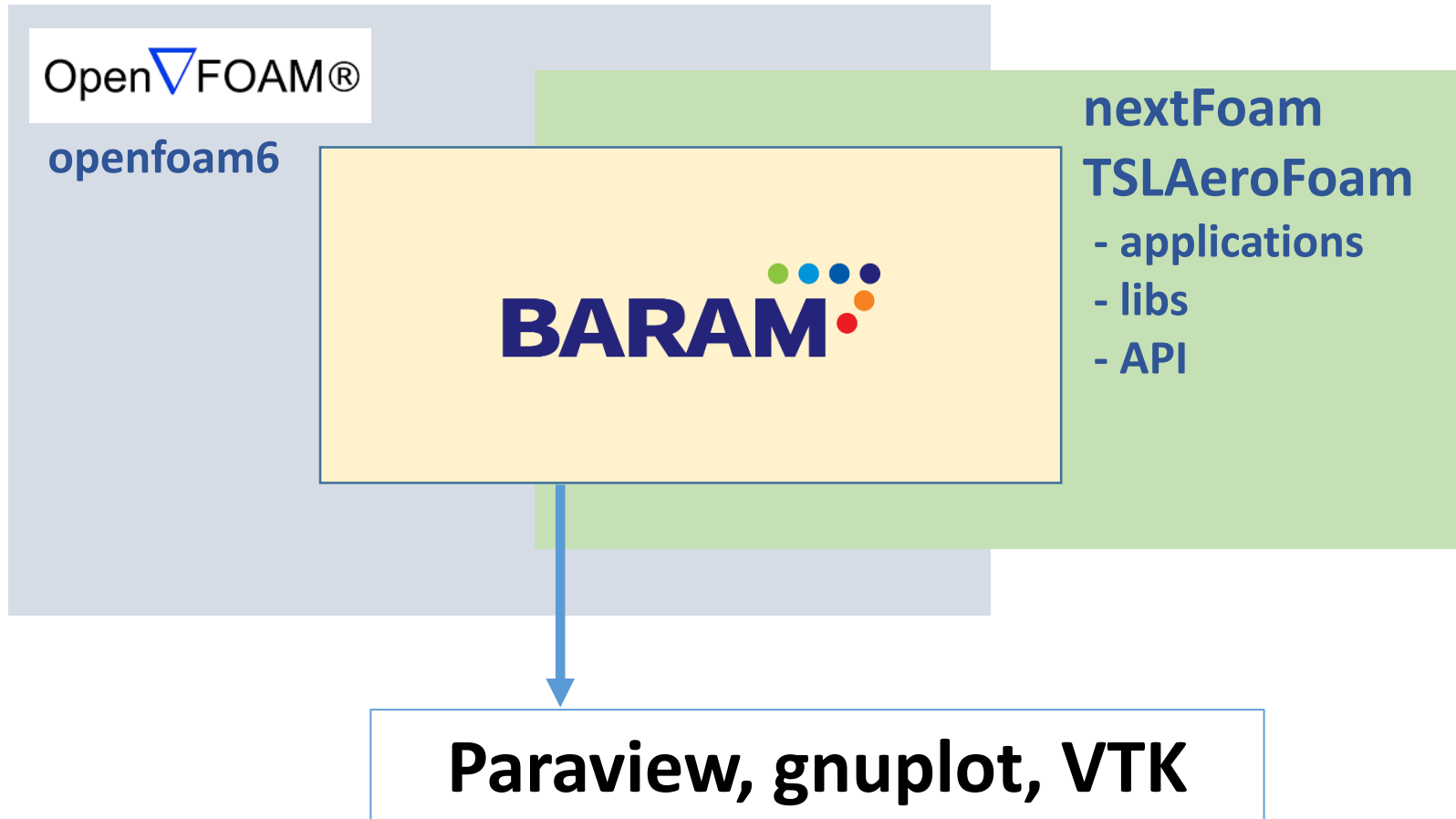


OpenFOAM 코드 개선

API 개발

Graphic Interface 개발

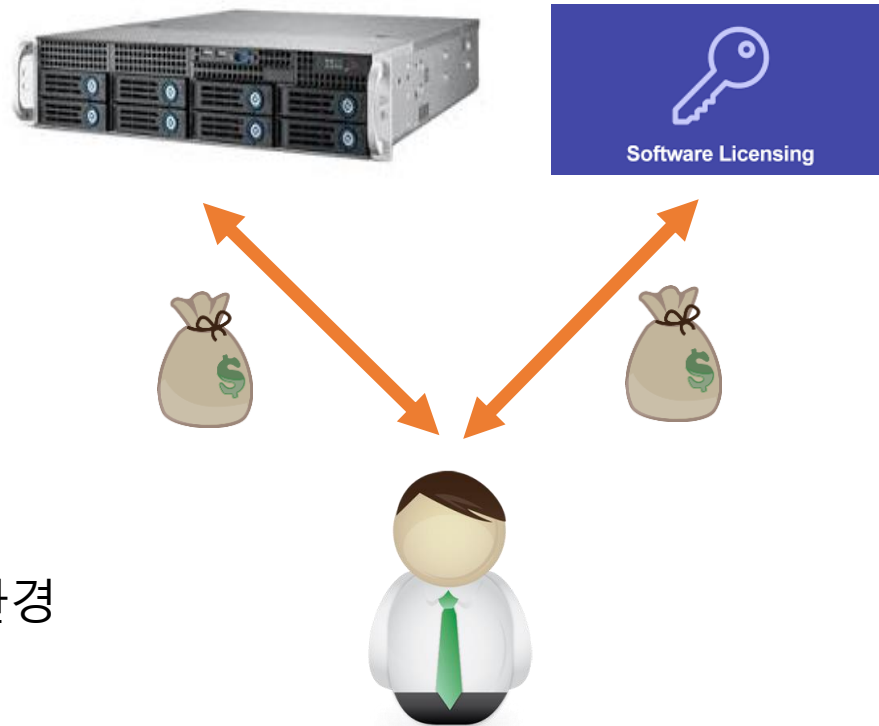
# BARAM의 구조 / 개발 방법



# 개발 방향 – CFD 사용 환경의 변화

## CFD 사용 방법의 Game Rule Change

- 클라우드, 공개소스, 인공지능, 디지털트윈, 메타버스...
- **새로운 사용 방식, 상용 프로그램의 대안 요구**

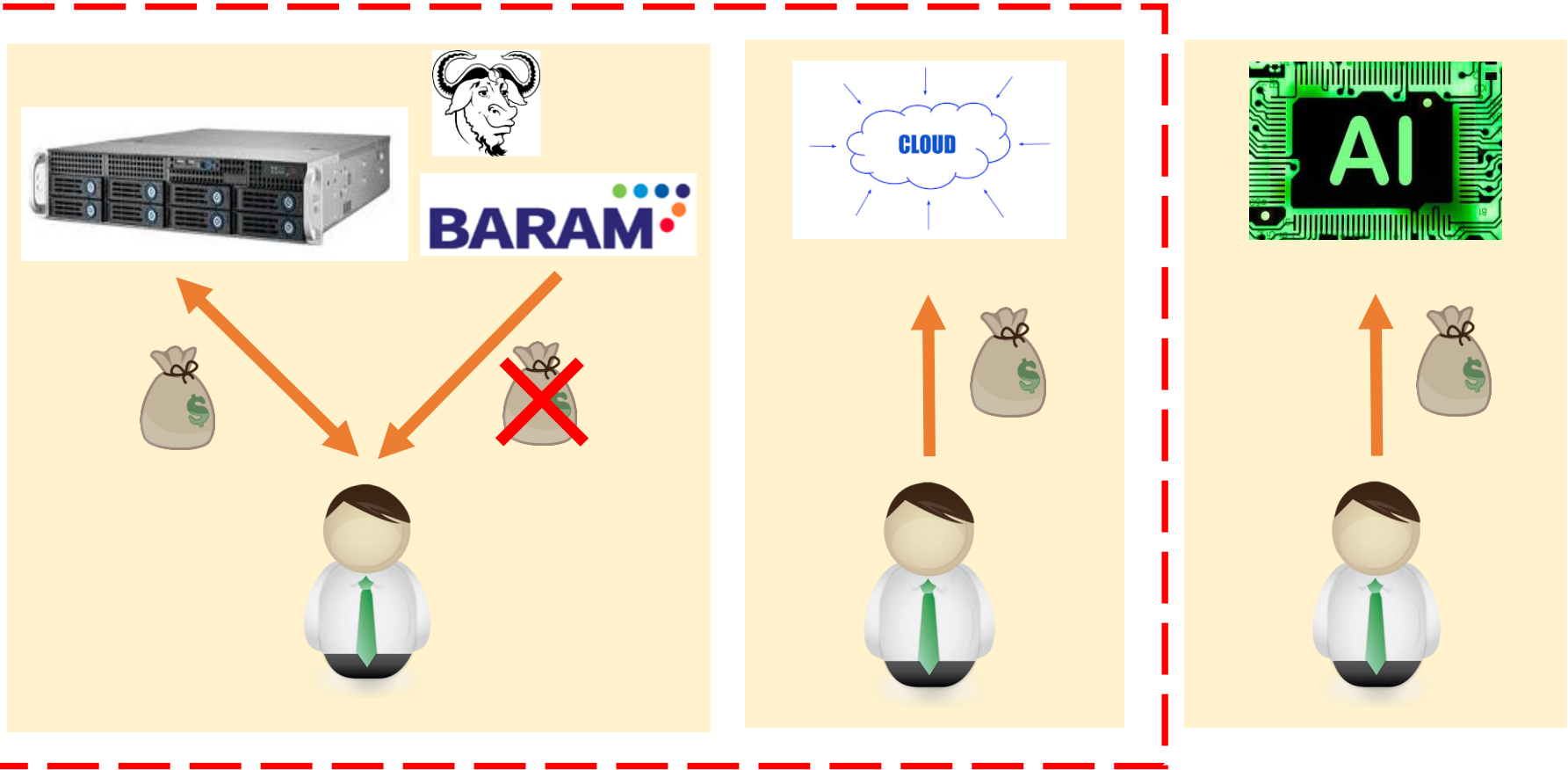


지금의 CFD 사용 환경



# 개발 방향 – CFD 사용 환경의 변화

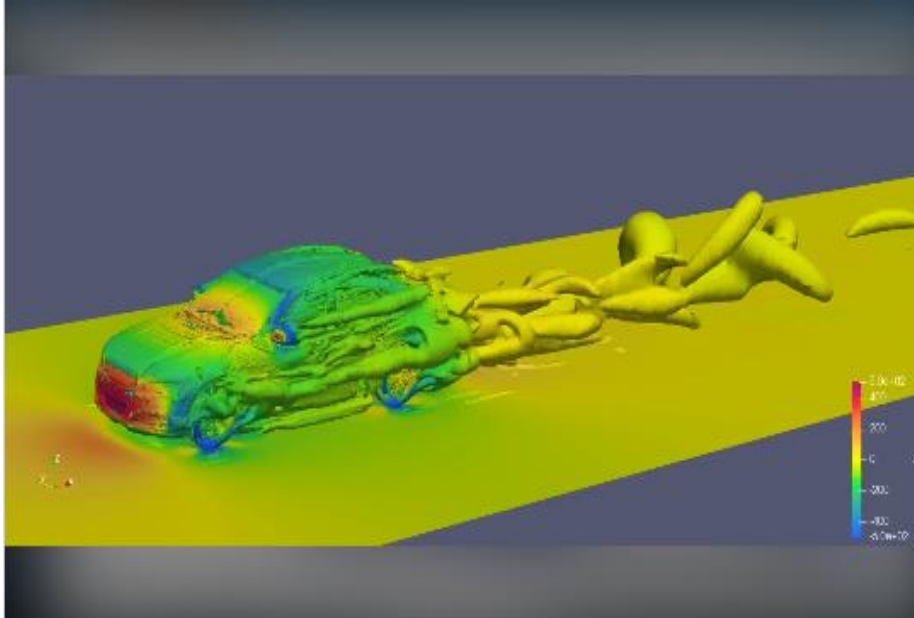
## CFD 사용 방법의 Game Rule Change



현재

미래

# BARAM in Rescale cloud



rescale baram - Google 검색 x Cloud HPC CAE Software | 인터 x

rescale.com/ko/software/

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If you decline, your information won't be tracked when you visit this website. A single cookie will be used in your browser to remember your preference not to be tracked.

Accept Decline

Workflow mxnet NAMD NEK

Nek5000 Interactive Network Simulator NEURON **NEXTfoam BARAM** **NEXTfoam BARAM Interactive Workflow** Nexus Suite Reservoir Simulation

NLopt Nolearn Notepad++ OpenCV NVIDIA OpenCL NWChem

Oasys Software Suite (FLEXlm License) Oasys Software Suite E2E (Desktop (LM-X License)) octave OMNIS OMNIS Interactive Workflow

20200703\_Simpack.apk x G - rescale baram - Google x https://www.rescale.com x Cloud HPC CAE Software x 엔지니어링 데이터 과학자 x

rescale.com/ko/software/

Apps: Google: Clust... New Tab LaTeX Math Form... 대역선 - Google... FDS Validation... docker YouTube Maps 7월 월간브리핑[3... Reading list

rescale 플랫폼 솔루션 인프라 소프트웨어 파트너 리소스 Rescale 소개 회원 가입 로그인

MSC MACHINIST GUI MSC Nastran Mxnet NAMD Nek5000 NKS5000 Interactive

Network Simulator NS-3 NLopt Nolearn Notepad++ OpenCV NVIDIA OpenCL NWChem

Oasys Software Suite (FLEXlm License) Oasys Software Suite E2E Desktop (LM-X License) octave OMNIS OMNIS Interactive Workflow OpenCV

**NEXTfoam BARAM Interactive Workflow**

Description BARAM is an GUI capable OpenFOAM®-based CFD solver for compressible and incompressible flow and heat transfer analysis. It is an open source program released by NextFoam under the GNU GPL license.

Industries

Available Versions 6.2.4

Licensing Not Required

# v6.3 기능

- Solver

- s(p)impleNFoam
- buoyantS(P)impleNFoam
- TSLAeroFoam
- speciesS(P)impleNFoam
- chtMultiRegionS(P)impleNFoam
- PCNFoam
- speciesPCNFoam
- speciesTSLAeroFoam

- Passive scalar

- cellZone

- MRF
- porous
- sliding mesh (비압축성)
- fixedVelocity

- Mesh

- snappyHexMesh
- cfMesh
- Mesh convert(fluent, starCCM+...)
- Create baffle, **cyclic**
- Check, scale, translate, rotate
- refineWallLayer
- **Conver to axi-symmetric/2D mesh**

- Source

- Uniform source
- **Time dependent source (polynomial, piecewise linear, csv file)**
- **fixedValue**

# v6.3 기능

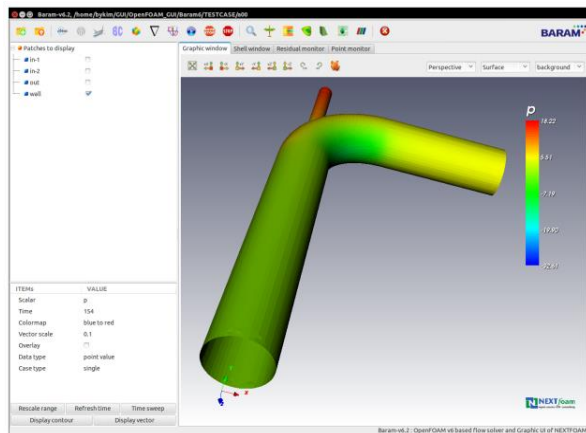
- Boundary conditions

- velocityInlet
- surfaceNormalVelocityInlet
- pressureInlet
- pressureOutlet, pressureOutletExt
- adiabaticWall(noSlip, slip, movingWall, rotation, translate)
- isothermalWall
- heatFluxWall
- convectionWall
- thermoCoupledWall
- Symmetry, empty, wedge, cyclic
- ABLInlet, ABLWall
- internalInterface
- rotationalPeriodic
- translationalPeriodic
- porousJump
- Fan
- farfieldRiemann
- subsonicInflow
- subsonicOutflow
- supersonicInflow
- supersonicOutflow
- Temporal profile
- Spatial profile

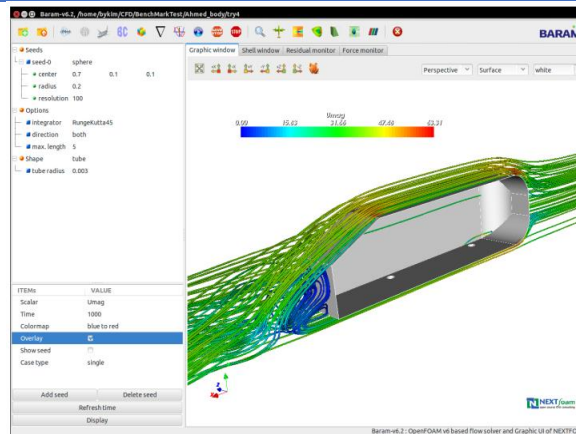
# v6.3 기능

- Monitoring / data extract
  - Residual
  - Force
  - Point, surface, **volume**(average, integral, **min, max, CoV**)
- Graphic post-processing
  - Patch scalar
  - Cutting plane
  - Iso-surface
  - Clip
  - Streamline
- Create fields
  - Vorticity, Q, yPlus, wallShearStress, wallHeatFlux, **totalPressure**
- Initialize / run option
  - setFields, mapFields, **potentialFoam**
  - **Passive scalar on/Off, scalar only**
  - **Set time to 0**
  - **Modify condition**
  - Batch run(Mach, AOA, AOS, **boundary value**)
- Numerical schemes
  - Discretization scheme(first/second)
  - Relaxation factors
  - Convergence criterion
  - Pressure-velocity coupling
  - nOuterCorrectors
  - **Sub-iteration(tol, relTol, min/maxIter)**
  - **nCorrectors**
- **Limit temperature**

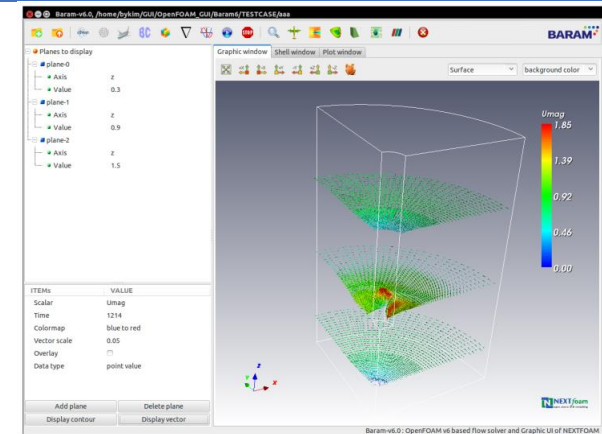
# Tutorials



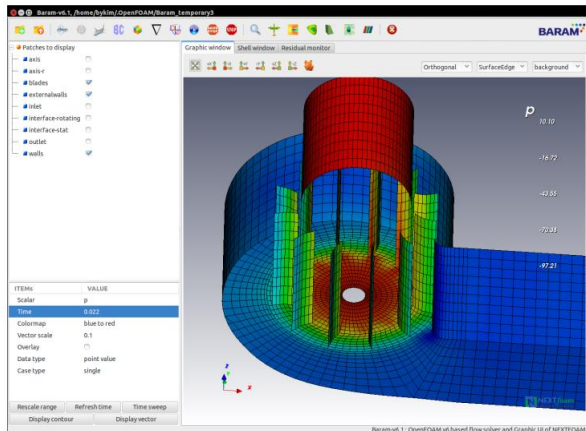
Mixing pipe  
- cfMesh 격자생성  
- 비압축성유동



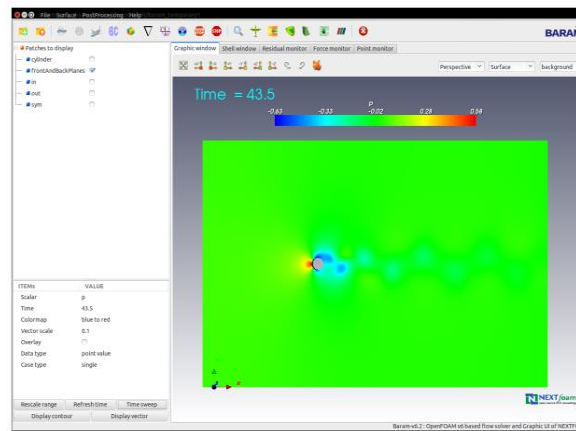
Ahmed body  
- cfMesh 격자생성  
- 비압축성 공력해석 검증



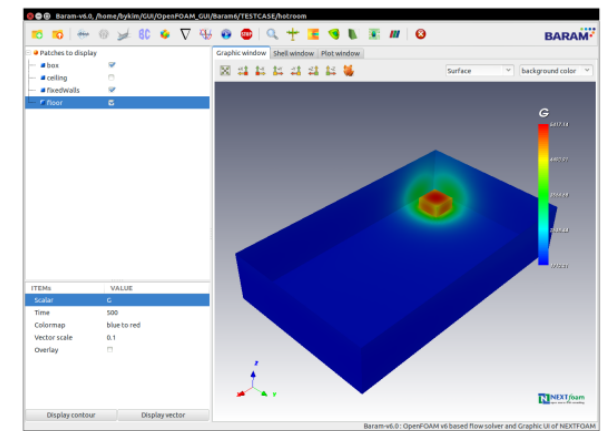
Mixer  
- baffle, periodic B.C  
- MRF



fan  
- Sliding mesh  
NEXTFoam  
open source CFD consulting

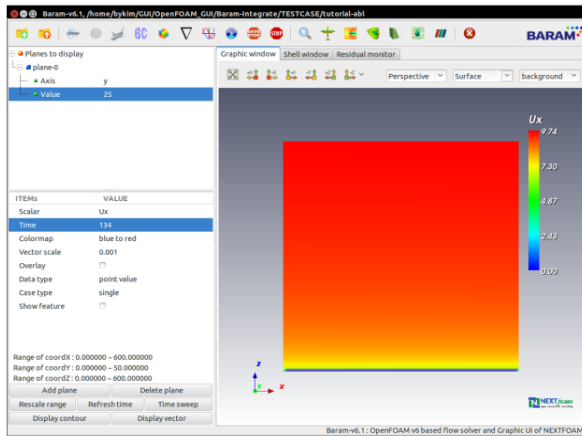


2d cylinder  
- 2차원 계산, 모니터링  
- Vortex shedding 검증

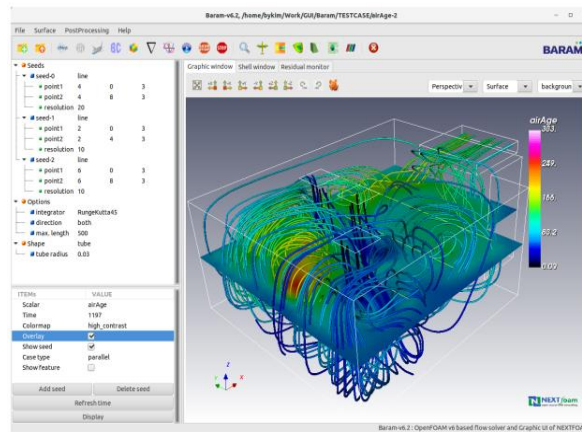


Hot room  
- Natural convection  
- Radiation

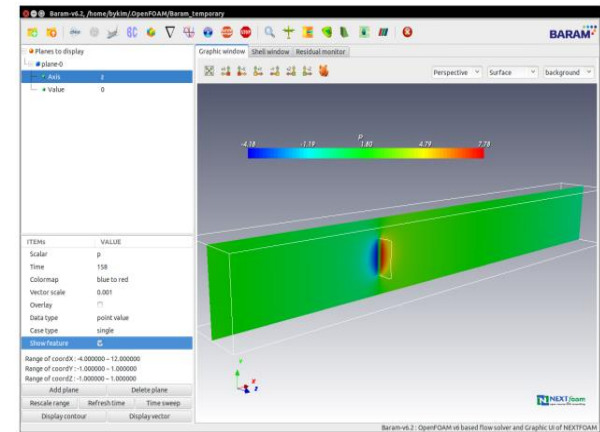
# Tutorials



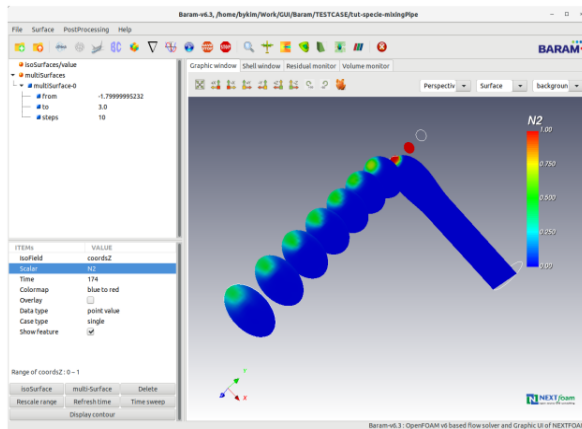
대기경계층  
- 경계조건 검증



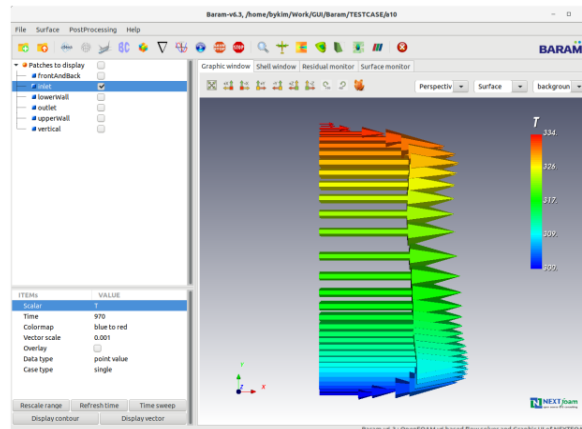
HVAC  
- Passive scalar  
- Air age



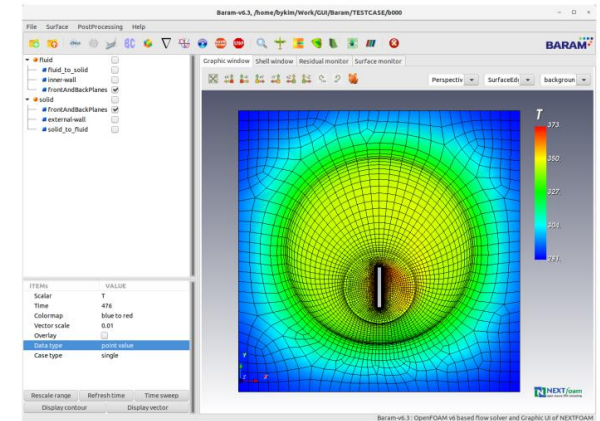
Duct flow  
- Internal boundary  
- Porous jump



Mixing pipe  
- Species transport



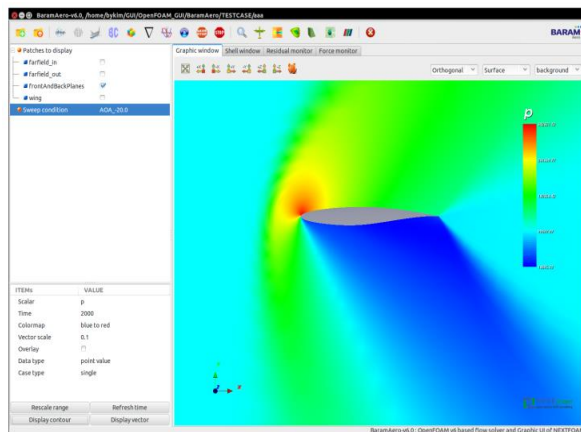
pitzDaily  
- Profile B.C  
- Time varying B.C



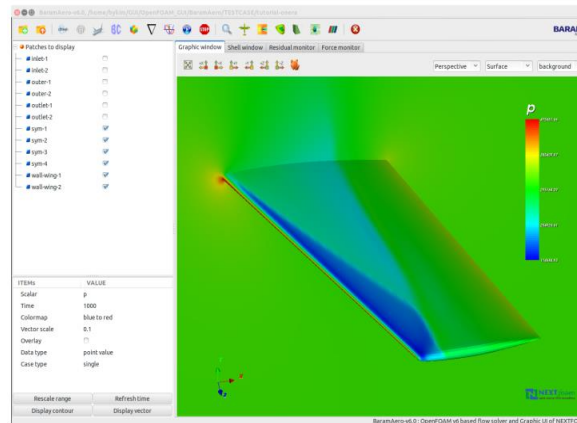
Hot bar  
- Conjugate heat transfer  
- multi-region



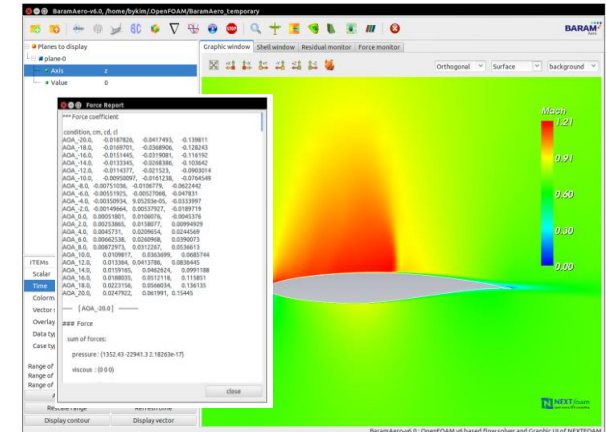
# Tutorials



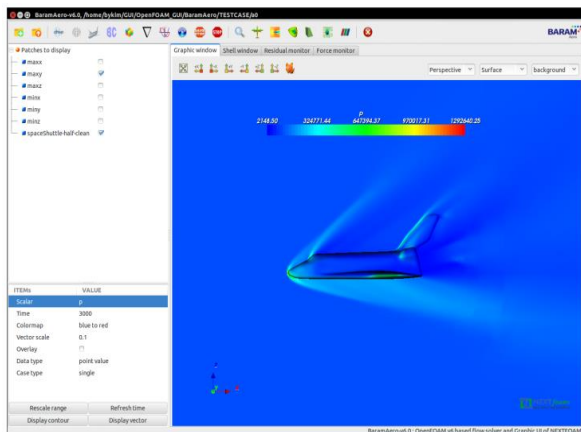
RAE2822 airfoil  
- 압축성 유동 검증



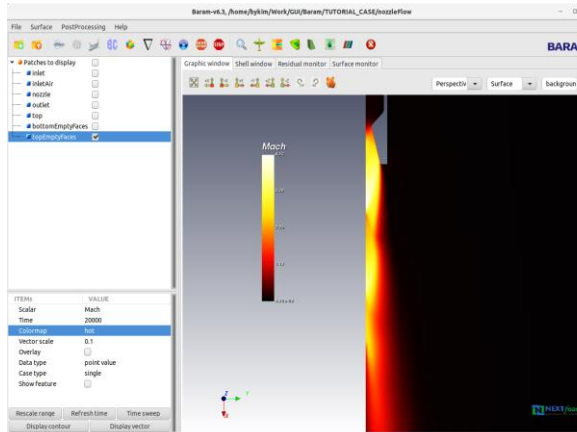
ONERA M6 wing  
- 압축성 유동 검증



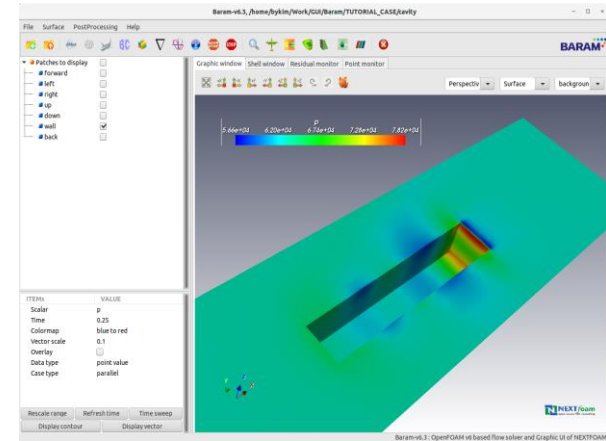
RAE2822 airfoil  
- AOA sweep



Space shuttle  
- cfMesh 격자생성  
- Supersonic flow  
NEXTfoam  
open source CFD consulting



Nozzle flow  
- axis-symmetric mesh generation  
- Supersonic flow



Cavity  
- 천음속 공동유동 검증  
- 압력기반 솔버(PCNFOam)



# 앞으로의 계획

- CFD 코드 기능 확장
  - 물리 모델, 솔버 성능
  - 격자 관련 문제
- 사용자환경 개선
  - 안정성, 그래픽 속도, 서버-클라이언트, Windows
- 지원 서비스 시스템 개발
  - 설치, 교육, 기술지원, 매뉴얼
  - Validation case, tutorial case

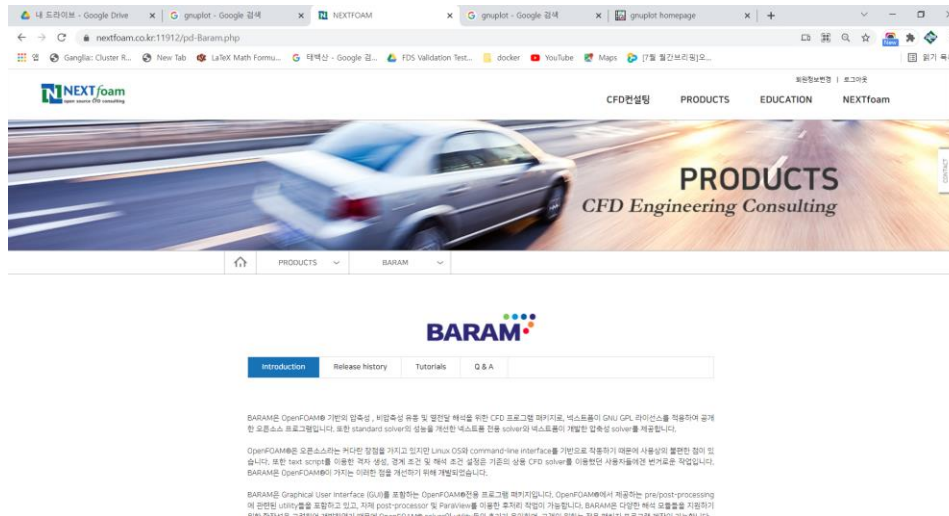
# 앞으로의 계획



- 다상유동
  - VOF
  - cavitation
- 압축성유동
  - transient  
TSLAeroFoam
- 설치 파일 문제
- Windows 문제

- 입자유동(DPM, spray)
- 난류(Low Re, RSM, DES/LES/DNS)
- 반응
- 격자 운동
- 솔버의 성능
- 격자 관련 문제
- 사용자환경 개선
- 매뉴얼/기술지원/교육...

# 감사합니다. 그리고...



<https://nextfoam.co.kr:11912/pd-Baram.php>



**WE'RE HIRING**

**2021 (주)넥스트폼  
경력/신입 채용공고**

넥스트폼 기술연구소에서 CFD엔지니어를 채용합니다.

|  |  |
|--|--|
| <p><b>모집분야</b><br/>CFD 해석실무</p> <p><b>직무내용</b></p> <ul style="list-style-type: none"> <li>- OpenFOAM을 이용한 열유체 해석 및 컨설팅</li> <li>- OpenFOAM 기반의 CFD 해석 프로그램 개발</li> <li>- 개발 프로그램에 대한 교육 및 기술지원</li> <li>- 기술영업</li> </ul> <p><b>채용인원</b><br/>서울 ○ 명</p> <p><b>근무조건 및 처우</b></p> <ul style="list-style-type: none"> <li>- 근무지역 : 서울</li> <li>- Environments : 정규직, 주5일근무, 4대보험, 연차휴가, 장기휴가 등</li> <li>- Benefits : 장기근속 안식월</li> </ul> <p><b>기타</b><br/>전문연구요원 병역특례 가능</p> <p><b>접수기간</b><br/>채용 시 까지</p> | <p><b>지원자격</b><br/>열유체 관련 전공자로 석사학위 이상 소지자<br/>- 관련학과 : 기계, 항공우주, 조선해양, 항공, 건축, 토목 등</p> <p><b>전형절차</b><br/>1차) 서류전형<br/>2차) 기술/인성 면접</p> <p><b>지원방법</b></p> <ul style="list-style-type: none"> <li>- 제출서류 : 1. 이력서<br/>2. 자기소개서 (최근 연구내용 포함)</li> <li>- 제출방법 : 이메일 (kjlee@nextfoam.co.kr, Tel. 070-8796-3025)</li> <li>- 제출된 서류는 반납되지 않으며, 합격자에 한해서 개별 통보합니다.</li> </ul> <p><b>문의처</b><br/>(주)넥스트폼 채용담당자<br/>Tel. 070-8796-3025<br/>kjlee@nextfoam.co.kr</p> <p><input type="checkbox"/> 하루동안 이 장을 열지 않음 <span style="border: 1px solid black; padding: 2px;">닫기</span></p> |
|--|--|

# Species transport solver – 개요

- 화학 반응없이 화학종 혼합을 계산할 수 있는 솔버
- Standard solver는 reactingFoam, fireFoam 등의 연소 솔버가 있지만...
- 비현실적인 온도 분포
  - Vijaya Kumar의 modifiedReactingFoam 참조
- Diffusivity 설정 기능 부족
  - Turbulent Schmidt No., mass diffusivity 추가
- 정상상태 솔버가 없음
- 압축성 솔버가 없음
- 개발 솔버
  - species(P)impleNFoam, speciesPCNFoam, speciesTSLAeroFoam

# Species transport solver – 개발 방법

1. speciesS(P)impleNFoam.C 코드 제작
  - buoyantS(P)impleNFoam 기반으로 수정
2. 화학종전달방정식 코드 작성(YEqn.H)
  - modifiedReactingFoam 의 YEqn.H 기반으로 수정
3. 에너지 방정식 수정
4. createFields 코드 수정

# Species transport – 솔버

## speciesSimpleNFoam.C

```
...
#include "fvCFD.H"
#include "turbulentFluidThermoModel.H"
#include "radiationModel.H"
#include "simpleControl.H"
#include "fvOptions.H"
#include "momentum.H"
#include "finiteVolumeFunctions.H"
#include "globalIOFunctions.H"
#include "constrainPhi.H"
#include "constrainPhig.H"

#include "rhoReactionThermo.H"
// *****

int main(int argc, char *argv[])
{
...
    #include "createFields.H"
    #include "createFieldRefs.H"
...
    while (simple.loop())
...
        #include "UEqn.H"
        #include "pEqn.H"
        turbulence->correct();

        #include "YEqn.H"
        #include "EEqn.H"

        #include "updateDensity.H"
...
    }
...
}
```

## speciesPimpleNFoam.C

```
...
#include "fvCFD.H"
#include "rhoThermo.H"
#include "turbulentFluidThermoModel.H"
#include "radiationModel.H"
#include "pimpleControl.H"
#include "fvOptions.H"
#include "fvcSmooth.H"
#include "momentum.H"
#include "finiteVolumeFunctions.H"
#include "globalIOFunctions.H"
#include "localEulerDdtScheme.H"
#include "constrainPhi.H"
#include "constrainPhig.H"
#include "rhoReactionThermo.H"
// *****

int main(int argc, char *argv[])
{
...
    #include "createFields.H"
    #include "createFieldRefs.H"
...
    while (pimple.loop())
    {
...
        #include "UEqn.H"
        #include "YEqn.H"

        while (pimple.correct())
        {
            #include "pEqn.H"
...
        }
    }
}
```

# Species transport – YEqn.H

- 지배방정식

$$\frac{\partial}{\partial t}(\rho Y_i) + \nabla \cdot (\rho \vec{v} Y_i) = -\nabla \cdot \vec{J}_i + S_i$$

J : diffusion flux, S : Source term

$$\vec{J}_i = -\left(\rho D_{m,i} + \frac{\mu_t}{Sc_t}\right) \nabla Y_i$$

$D_{m,i}$  : mass diffusivity

$Sc_t$  : turbulent Schmidt number

reactingFoam에는 없는 turbulent Schmidt No. 와 mass diffusivity 고려

mvConvection->fvmDiv(phi,Yi) 사용하지 않음

```
{
    scalar Sct(diffusivities.lookupOrDefault("Sct",0.7));
    dimensionedScalar Dm(diffusivities.lookup("Dm"));

    volScalarField Yt(0.0*Y[0]);

    forAll(Y, i)
    {
        if (i != inertIndex && composition.active(i))
        {
            volScalarField& Yi = Y[i];

            fvScalarMatrix YiEqn
            (
                fvm::ddt(rho, Yi) // for PIMPLE
                //+ mvConvection->fvmDiv(phi, Yi)
                + fvm::div(phi, Yi)
                - fvm::laplacian(rho*Dm + turbulence->mut())/Sct, Yi)
            ==
            fvOptions(rho, Yi)
        );

        YiEqn.relax();

        fvOptions.constrain(YiEqn);

        YiEqn.solve(mesh.solver("Yi"));

        fvOptions.correct(Yi);

        Yi.max(0.0);
        Yt += Yi;
    }
}

Y[inertIndex] = scalar(1) - Yt;
Y[inertIndex].max(0.0);
}
```

# Species transport – EEqn.H

- 지배방정식

$$\frac{\partial}{\partial t}(\rho h) + \nabla \cdot (\rho \vec{v} h) + \frac{\partial}{\partial t}(\rho K) + \nabla \cdot (\rho \vec{v} K) = \frac{\partial p}{\partial t} + \rho \vec{v} \cdot \vec{g} - \nabla \cdot Q - \nabla \cdot \sum \vec{J}_i h_i$$

K : total kinetic energy

Q : conductive heat flux

J : diffusion flux

enthalpy transport due to  
inter-species diffusion

$$Q = \alpha_{eff} \nabla h + \alpha_{eff} (\sum h_i \nabla Y_i)$$

modifiedReactingFoam 에서 추가된 항  
- reactinfFoam 에는 없음  
- 이 부분이 없으면 비현실적인 온도분포 발생

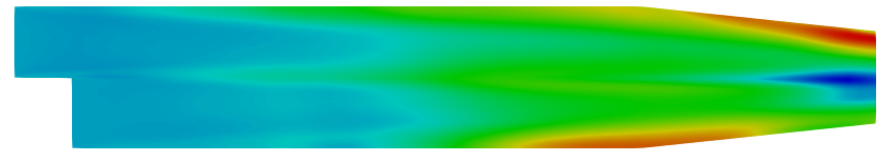
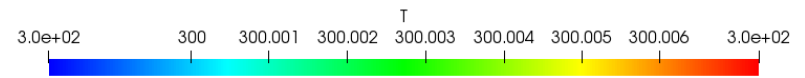
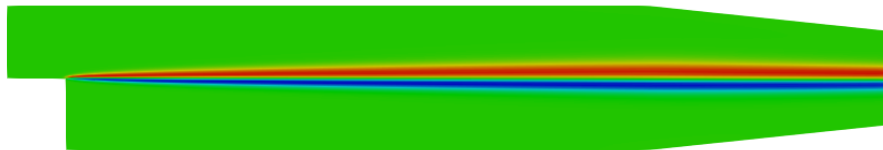
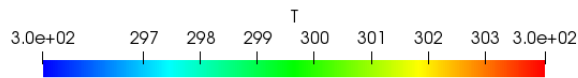
$$\vec{J}_i = - \left( \rho D_{m,i} + \frac{\mu_t}{Sc_t} \right) \nabla Y_i$$

modifiedReactingFoam에서는  $\mu_{eff}$  사용



# EEqn.H

- 온도분포 검증
  - pitzDaily, steady, inlet velocity = 1m/s

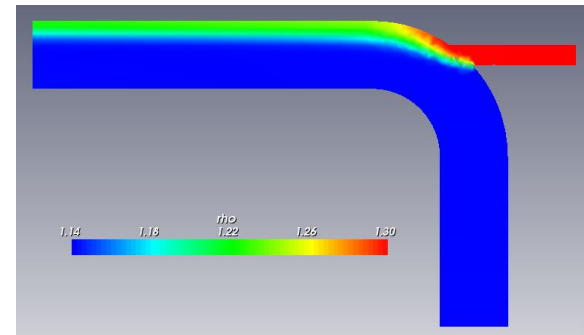
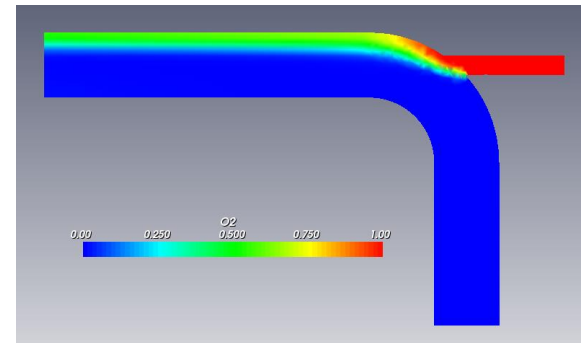
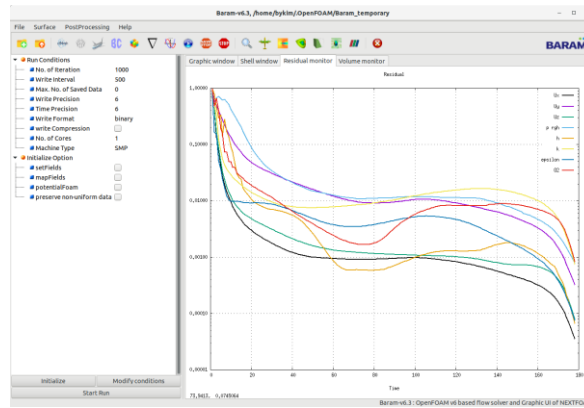
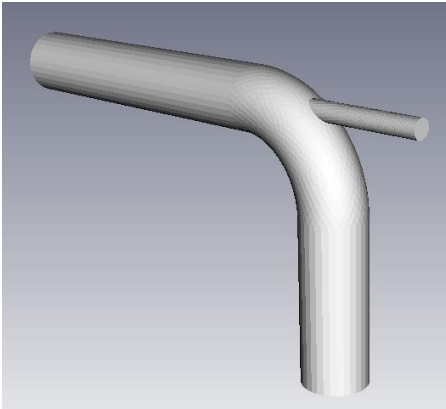


modifiedReactingFoam 수정 내용

소수점 이하 자리수는 limiter 때문에 생김

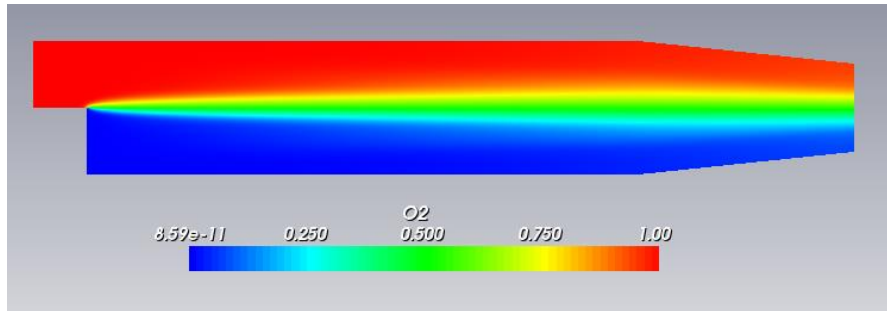
# Test case 1

- in-1(아래쪽 입구)에는 N2, in-2(위쪽 좁은 입구)에는 O2가 1m/s으로 공급
- steady

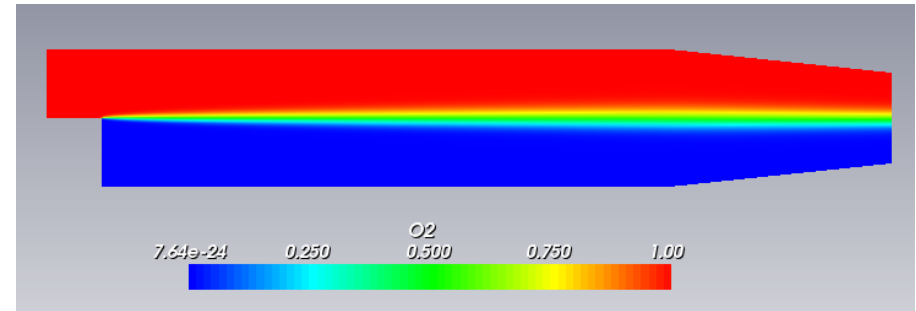


# Test case 2

- pitzDaily, steady, inlet velocity = 1m/s
- Turbulent Schmidt No.의 영향 : 0.1 and 0.7



Sct = 0.1



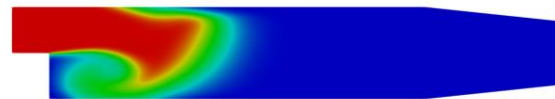
Sct = 0.7

# Test case 3

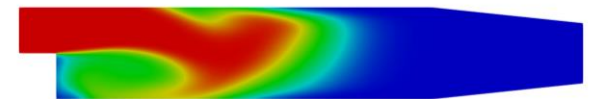
- pitzDaily, transient, inlet velocity = 1m/s
- 초기조건은 전체가 O2
- 입구에서 N2가 유입



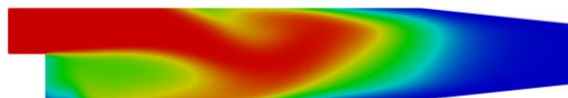
Time: 0.050000



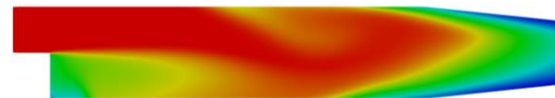
Time: 0.150000



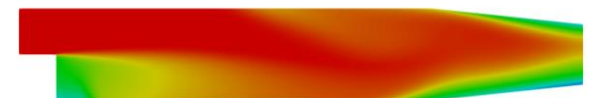
Time: 0.250000



Time: 0.350000



Time: 0.450000



Time: 0.550000

- YEqn.H에 thermal diffusion 추가

$$\vec{J}_i = - \left( \rho D_{i,m} + \frac{\mu_t}{S_{ct}} \right) \nabla Y_i - D_{T,i} \frac{\nabla T}{T}$$

- Mass diffusivity 보완
- Validation
- 압축성(speciesTSLAeroFoam)에서 에너지방정식 수정 사항 반영???