2020 한국전산유체공학회 통합학술대회
2020. 10. 20, 제주 매종글래드 호텔

오픈 소스 라이브러리를 활용한 CFD Workflow 자동화 기술 연구

Research on the Automation Technology for CFD Workflow Using Open Source Libraries

㈜넥스트폼

Convergence Technology Team

이 상 철

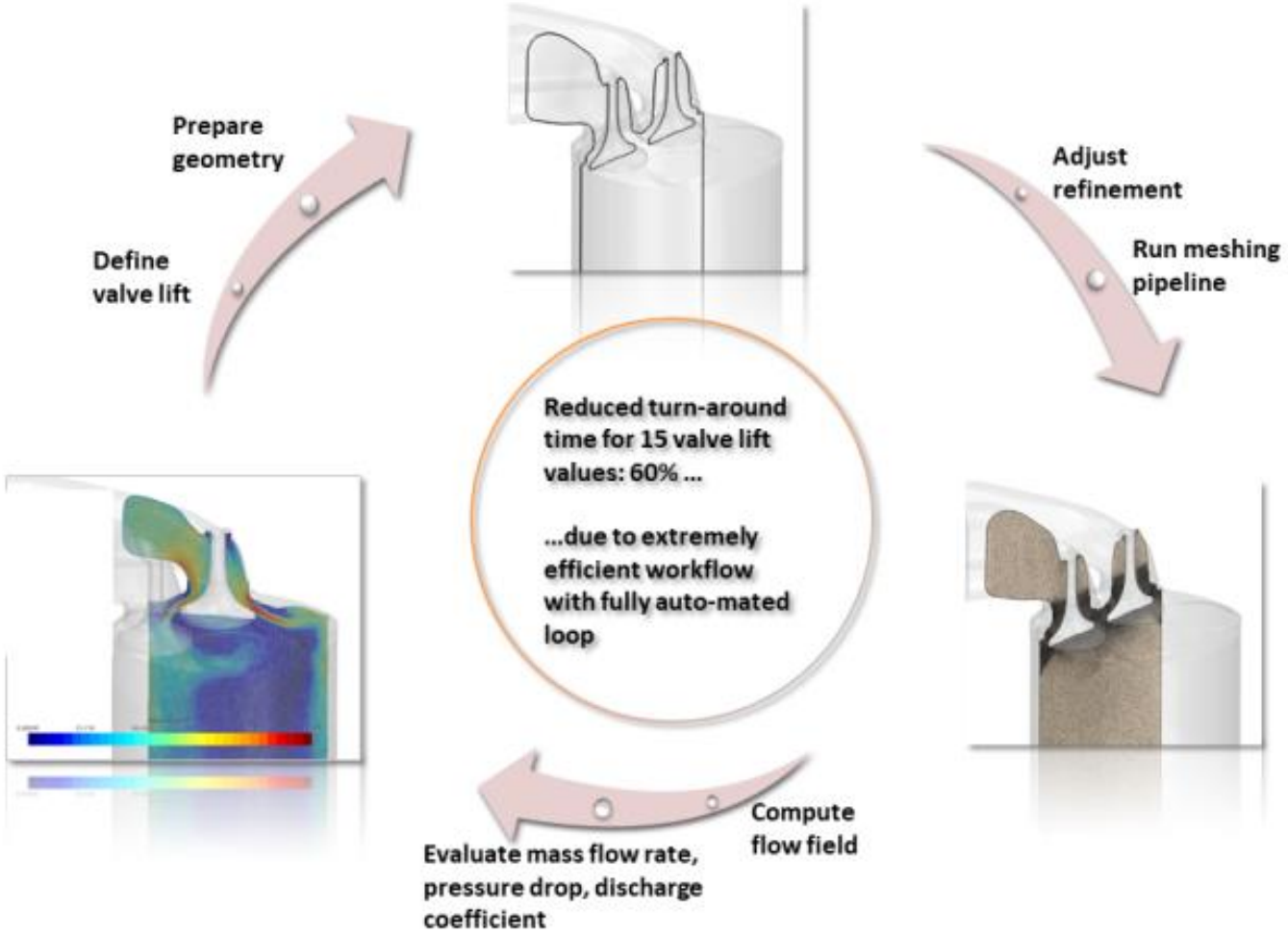
NEXTfoam
open source CFD consulting

Contents

- 연구 배경
- 연구 개요
- 핵심 요소기술 소개
- 향후 추가 계획

연구 배경

연구 필요성



Routine CFD Workflow

(출처: http://www.combustion-flow-solutions.com/cfs/en/extremely-efficient-cfd-workflow-flow-through-a-valve)

반복적, 시간 소모적 업무

↓

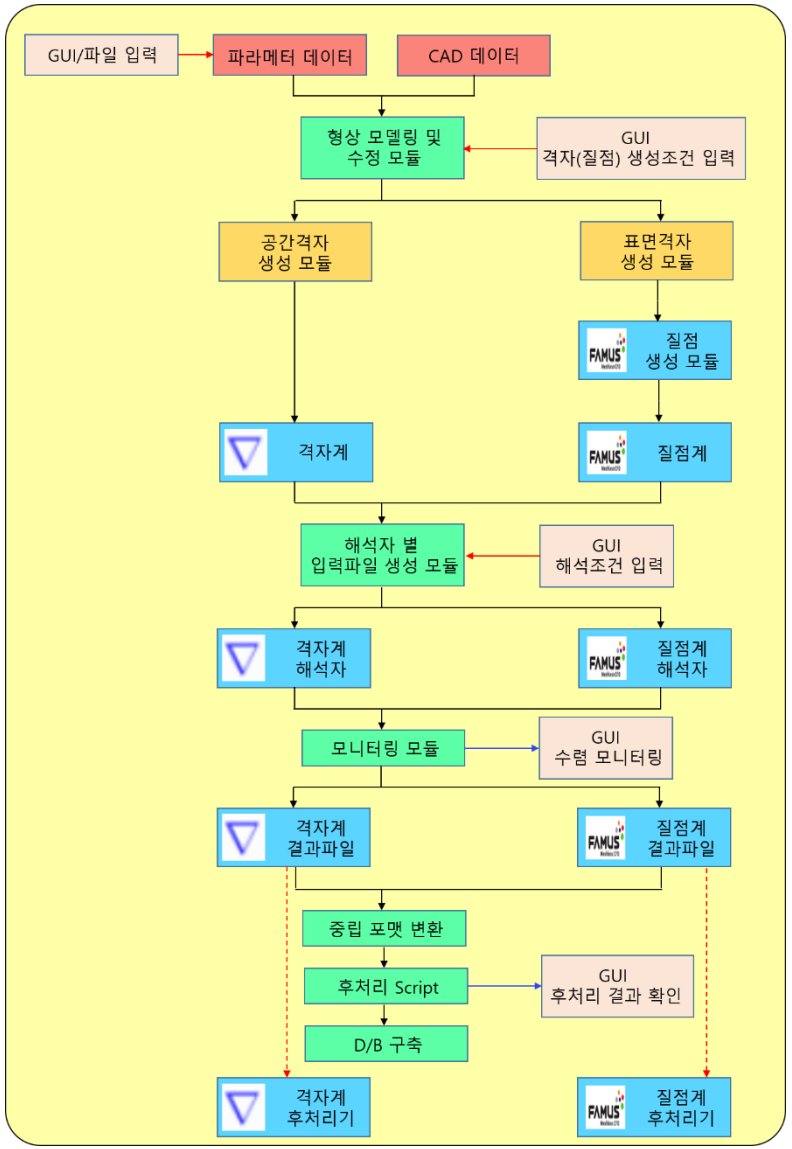
업무 자동화

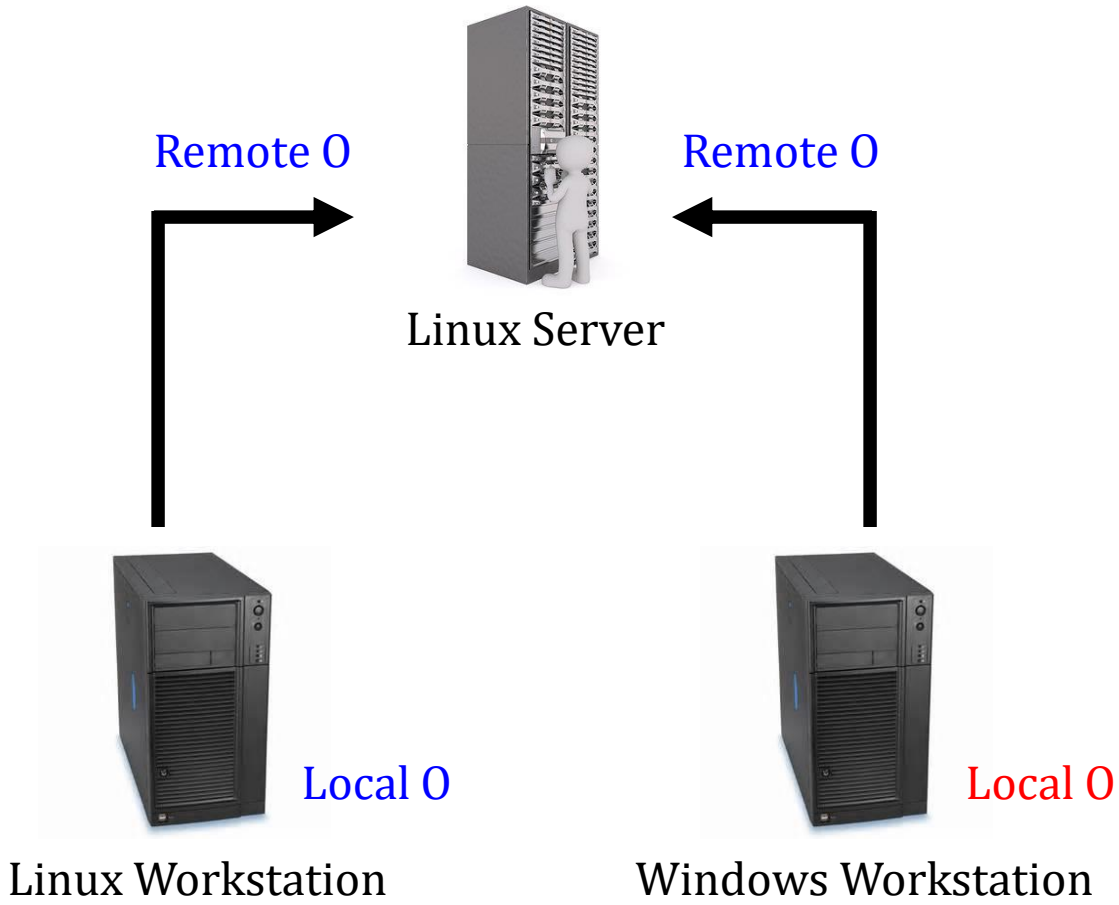
↓

효율적, 생산적 업무

연구 개요

연구 목표

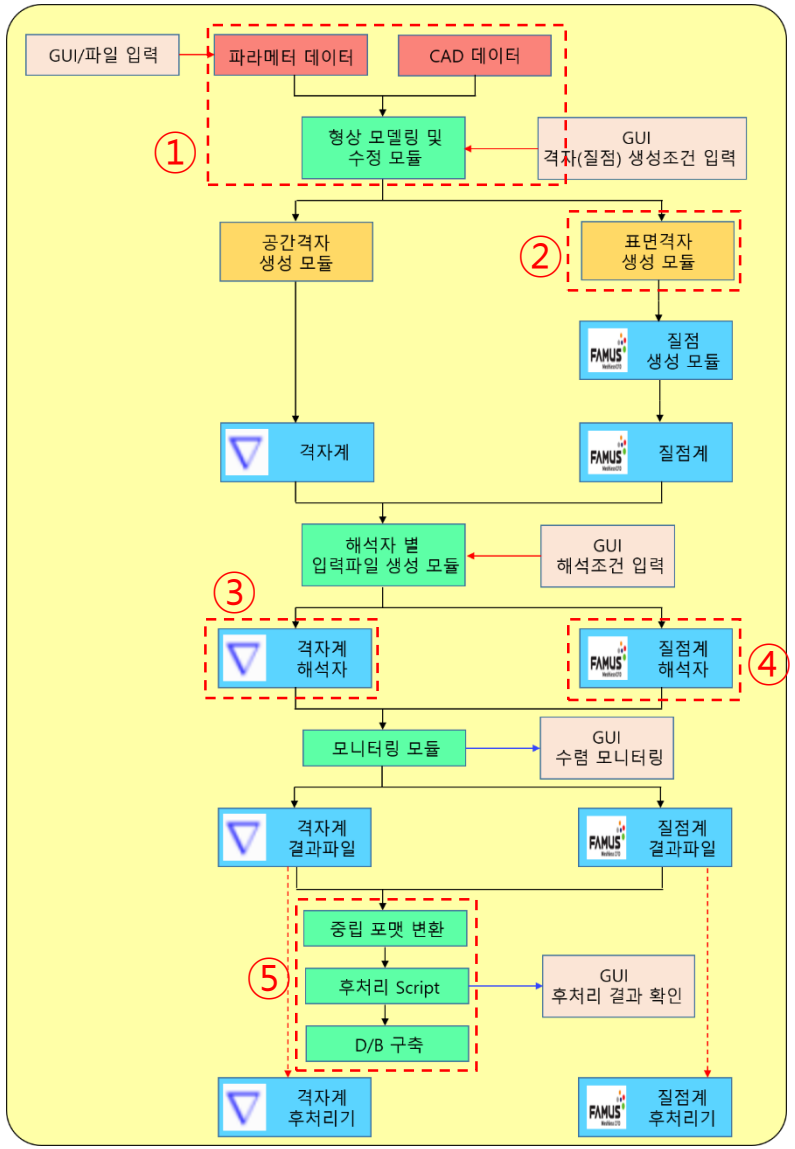




주 작업흐름 → GUI 입력 → GUI 출력

핵심 요소기술 소개

기 진행 개발기술



① 파라메터 기반 형상 모델링(OpenCascade)

② 표면격자 생성 모듈(Netgen)

③ 격자계 해석자(TSLAeroFoam)

④ 질점계 해석자(FAMUS)

⑤ 후처리 자동화 및 D/B 구축(VTK & MongoDB)

핵심 요소기술 소개

파라메터 기반 형상 모델링(OpenCascade)

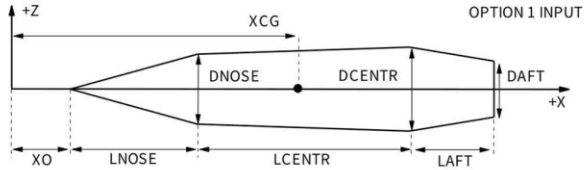
[Missile DATCOM의 형상 정의]

Centerbody – Axisymmetric, Elliptic

Nose – Cone, Ogive, Power, Haack, Karman

Afterbody – Cone, Ogive

Finset – Hex, NACA, Arc



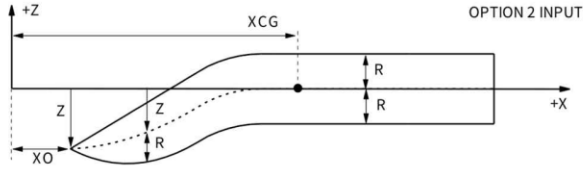
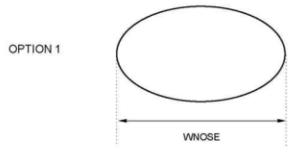
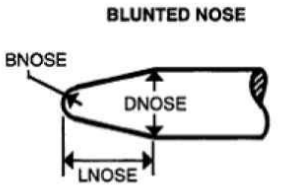
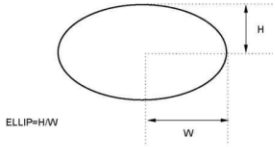


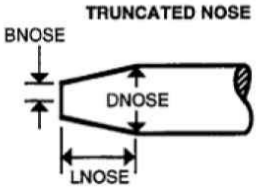
Figure 2. Axisymmetric Body Geometry Variables



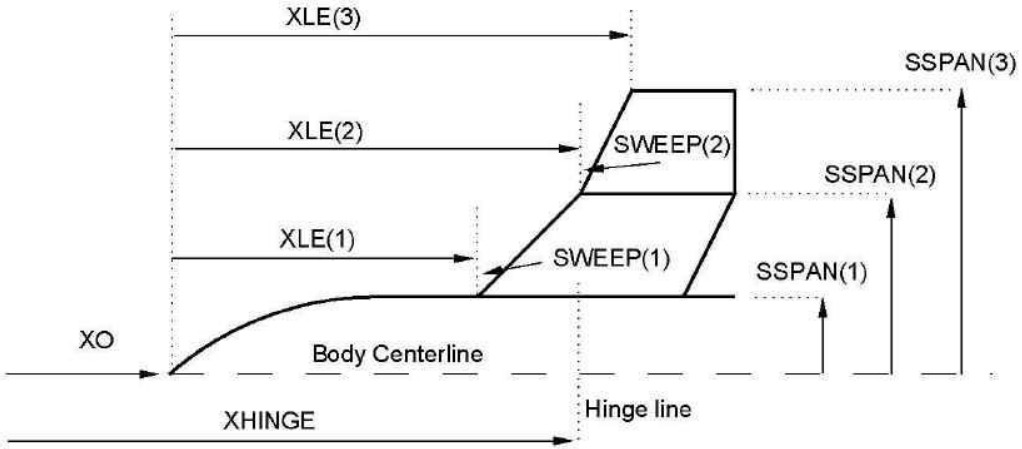


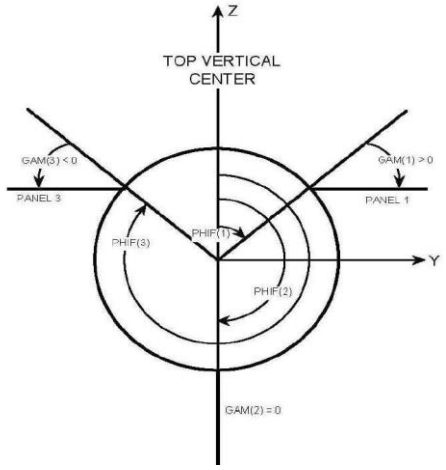
BNOSE = #.##
TRUNC = .FALSE.

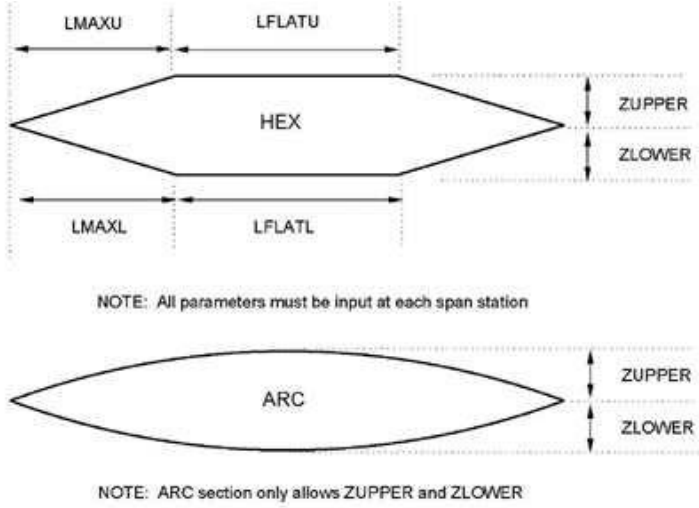




BNOSE = #.##
TRUNC = .TRUE.







핵심 요소기술 소개

파라메터 기반 형상 모델링(OpenCascade)(계속)

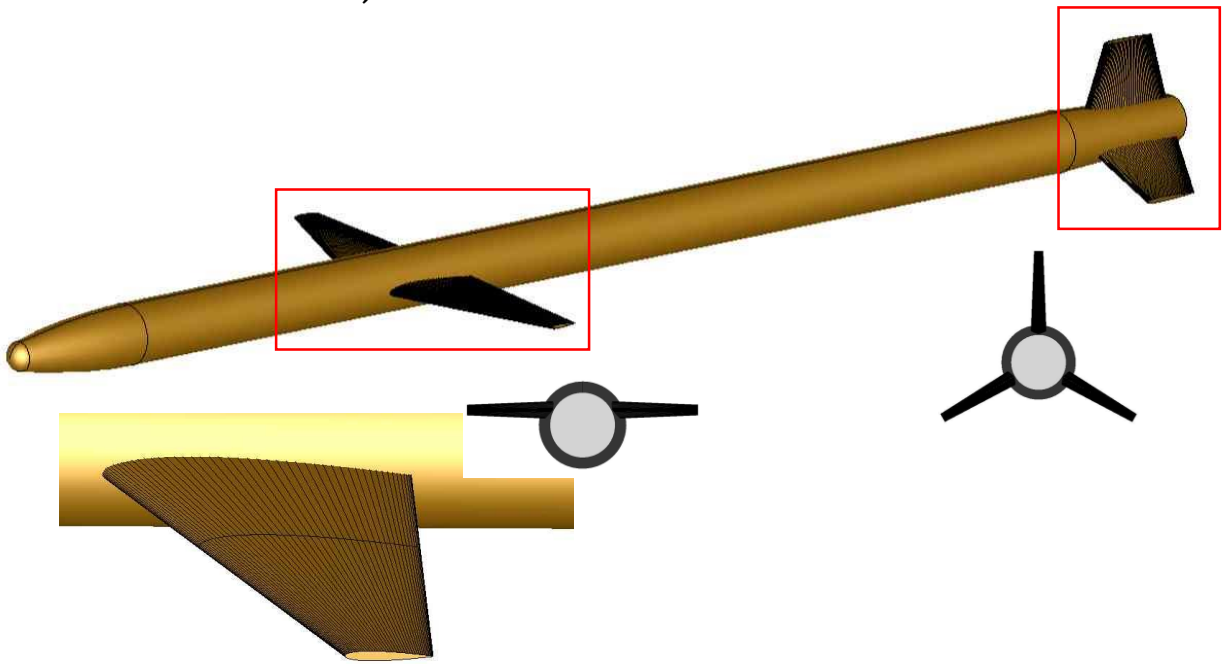
형상 #1

Centerbody – Axisymmetric (Ellipticity 1.0)

Nose – Ogive (blunted)

Afterbody – Cone

Finset – NACA, NACA



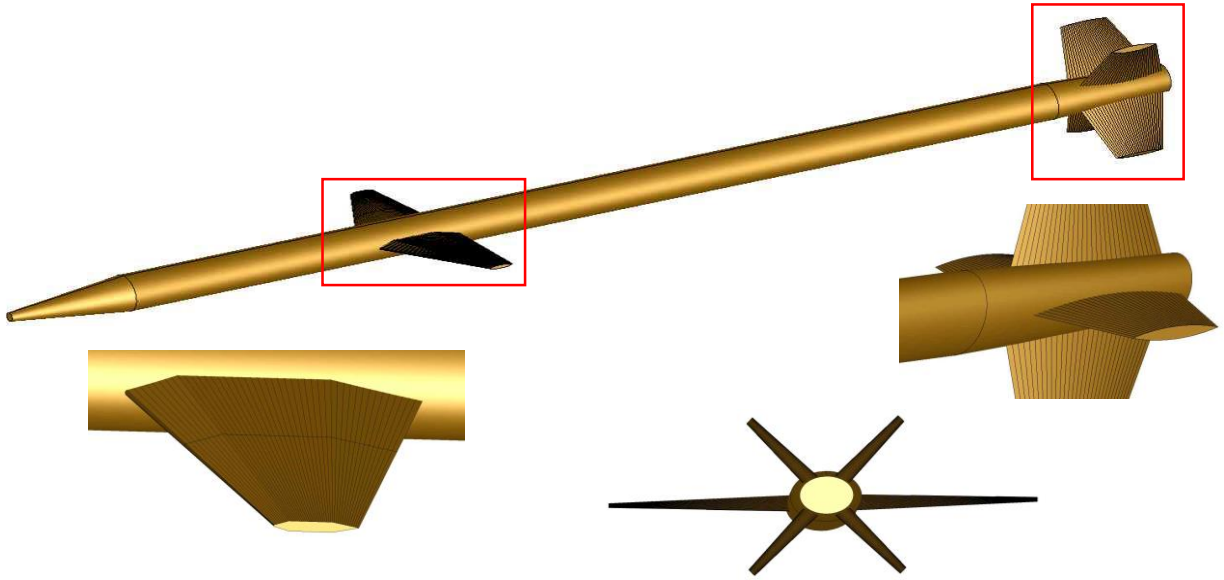
형상 #2

Centerbody – Elliptic (Ellipticity 0.5)

Nose – Cone (truncated)

Afterbody – Ogive

Finset – Hex, Arc



핵심 요소기술 소개

파라메터 기반 형상 모델링(OpenCascade)(계속)

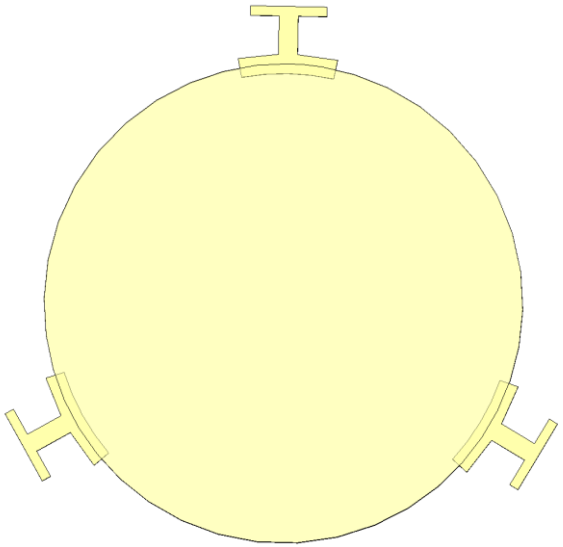
[Protuberance 형상 정의]

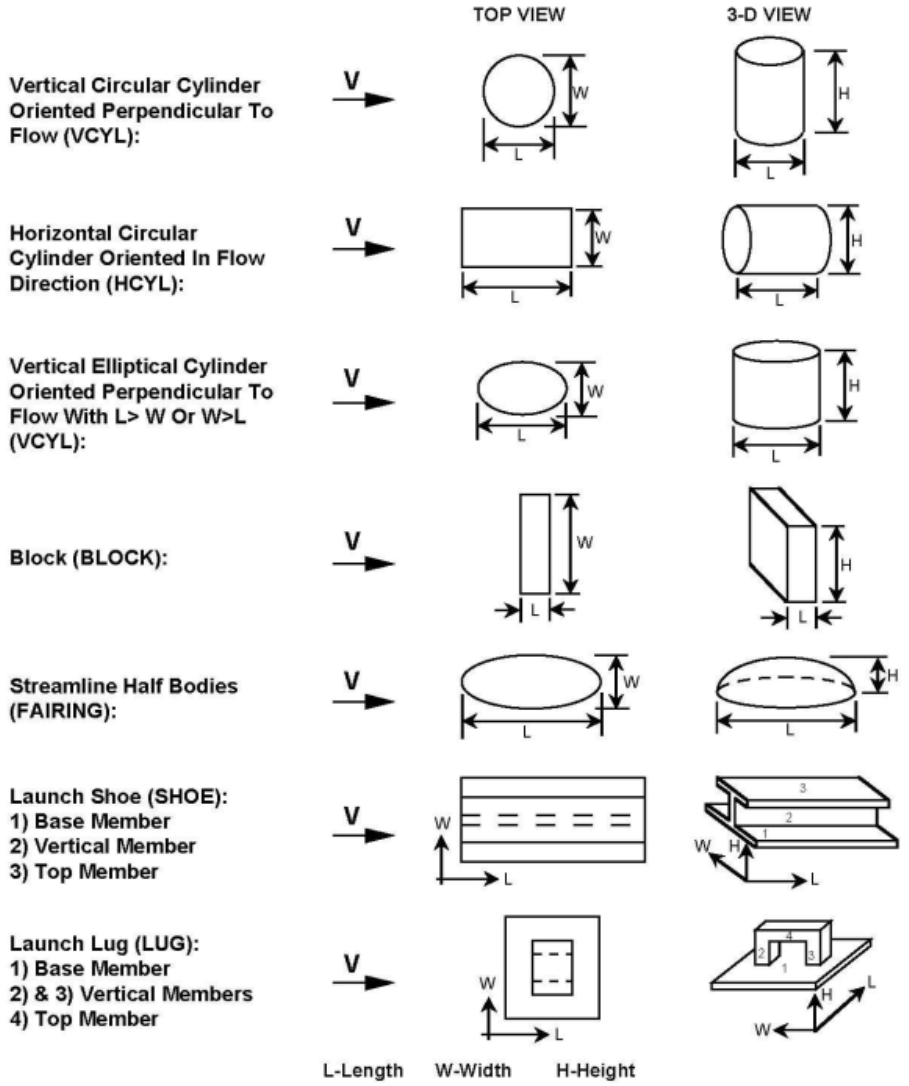
형상 – Length, Width, Height

부착 – 개수, 각도

Offset – Missile 표면에서 이격

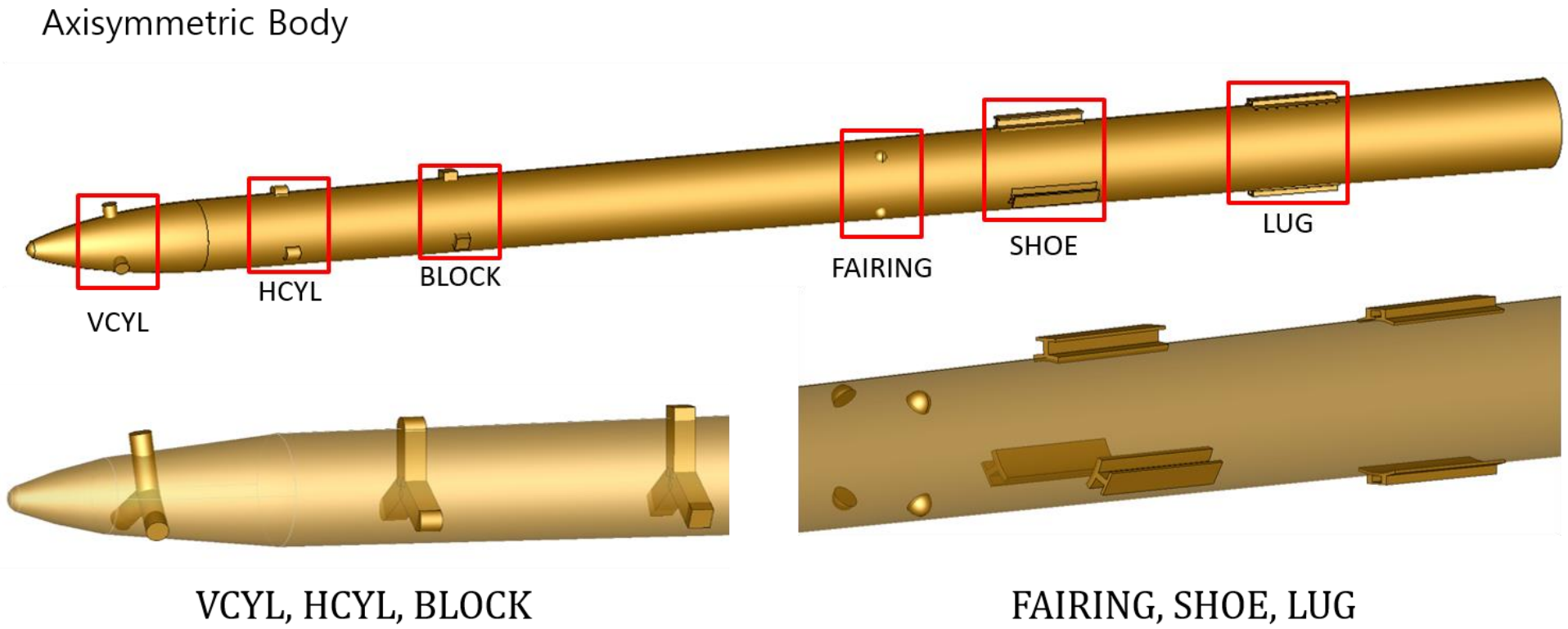
Missile Body 표면의 기울기를 고려하여 형상 생성





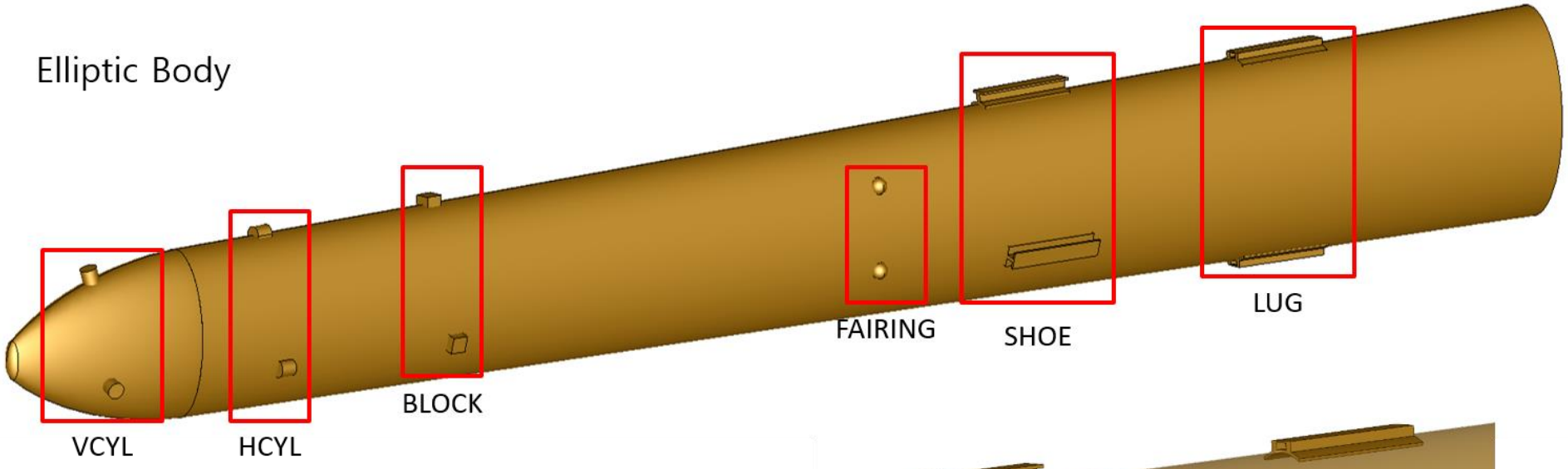
핵심 요소기술 소개

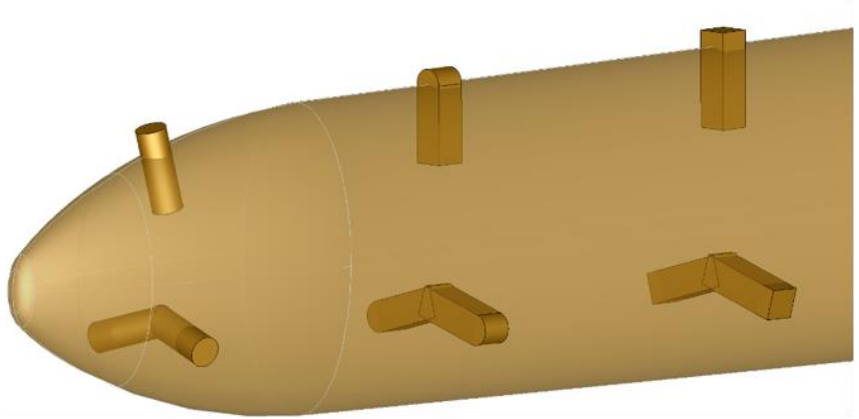
파라메터 기반 형상 모델링(OpenCascade)(계속)



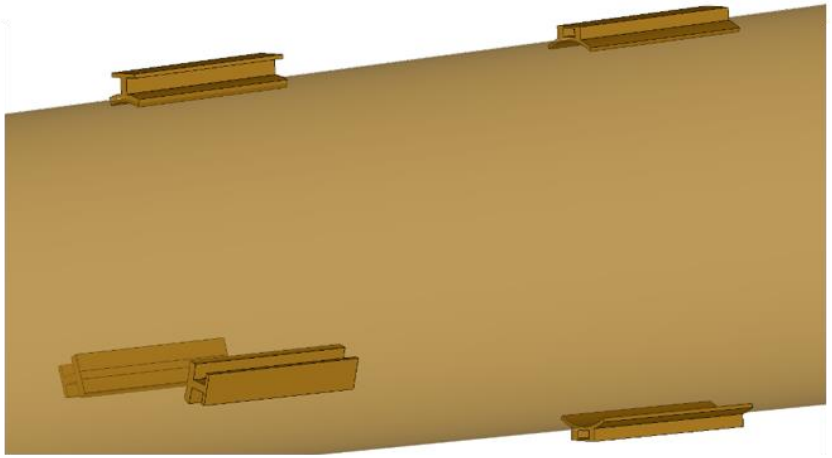
핵심 요소기술 소개

파라메터 기반 형상 모델링(OpenCascade)(계속)





VCYL, HCYL, BLOCK

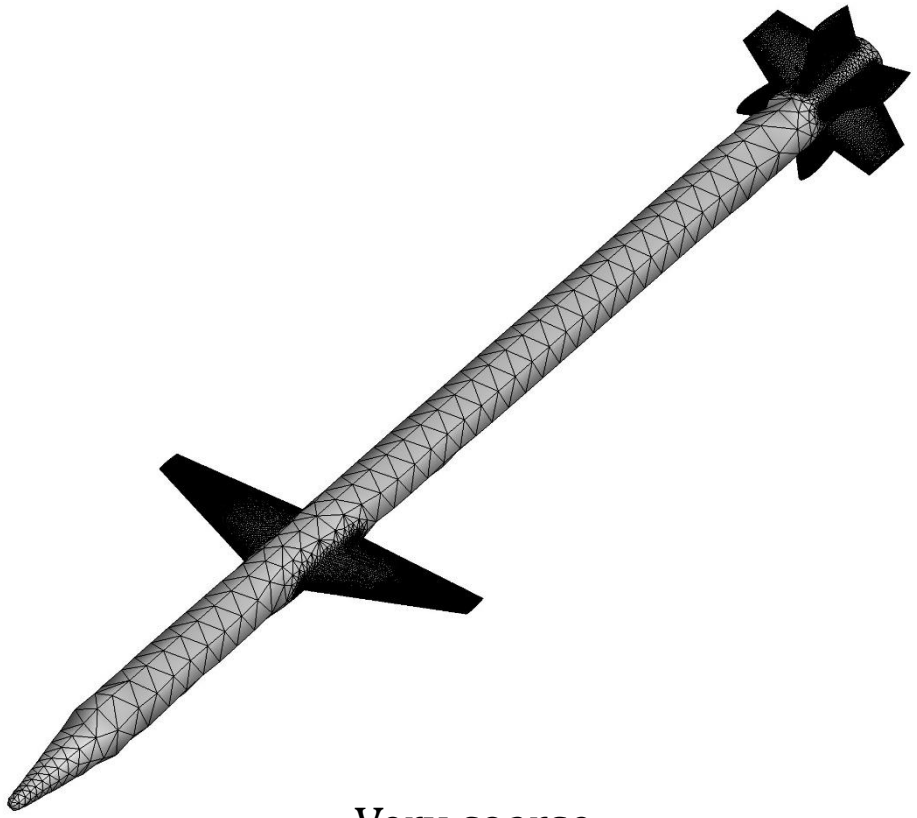


SHOE, LUG

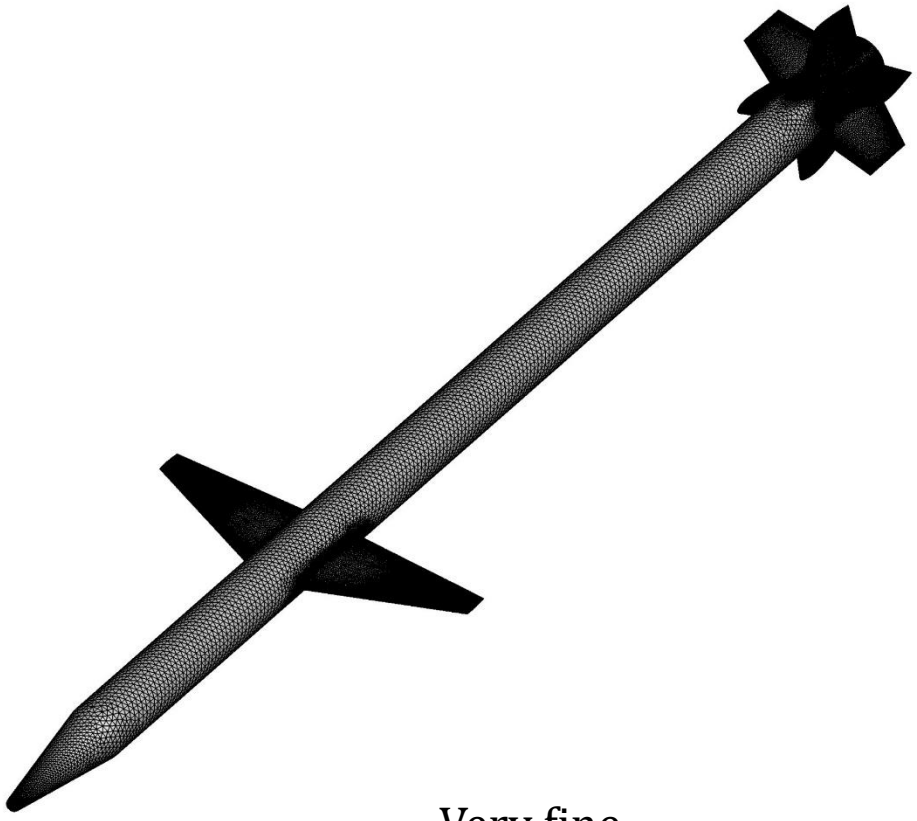
핵심 요소기술 소개

표면격자 생성 모듈(Netgen)

Fineness – Very coarse ~ Very fine (5 levels), User defined(본 옵션을 사용하면 Mesh size min/max값 이용)



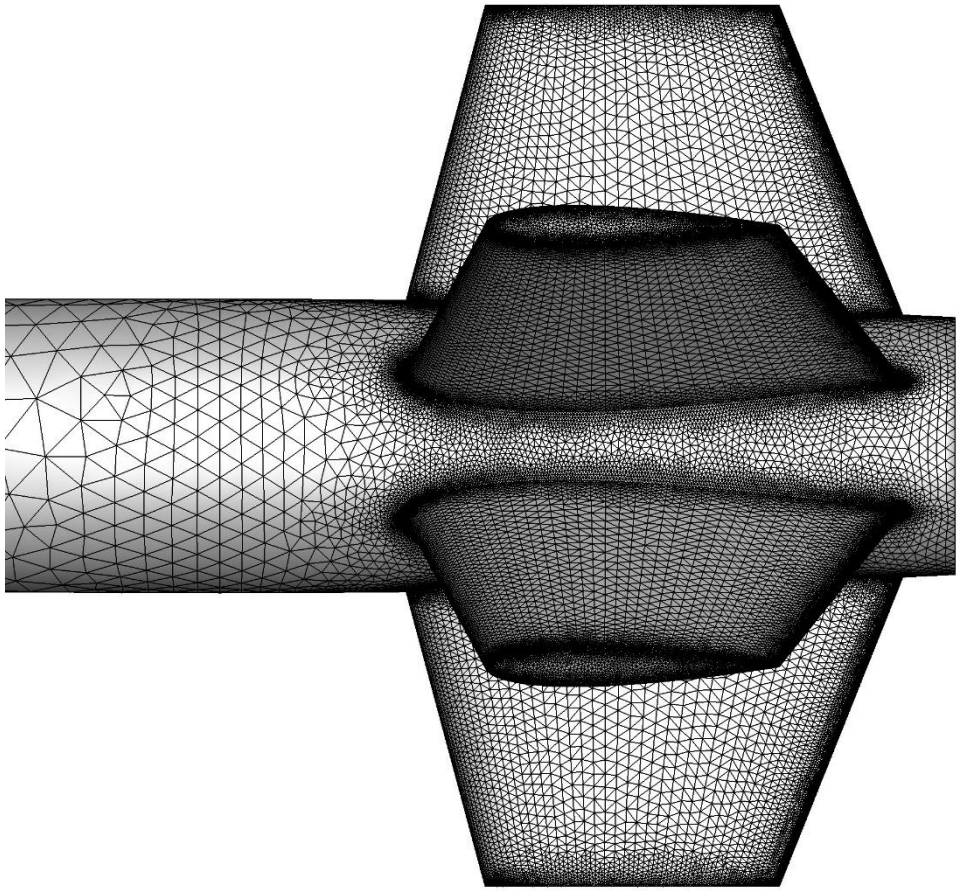
Very coarse



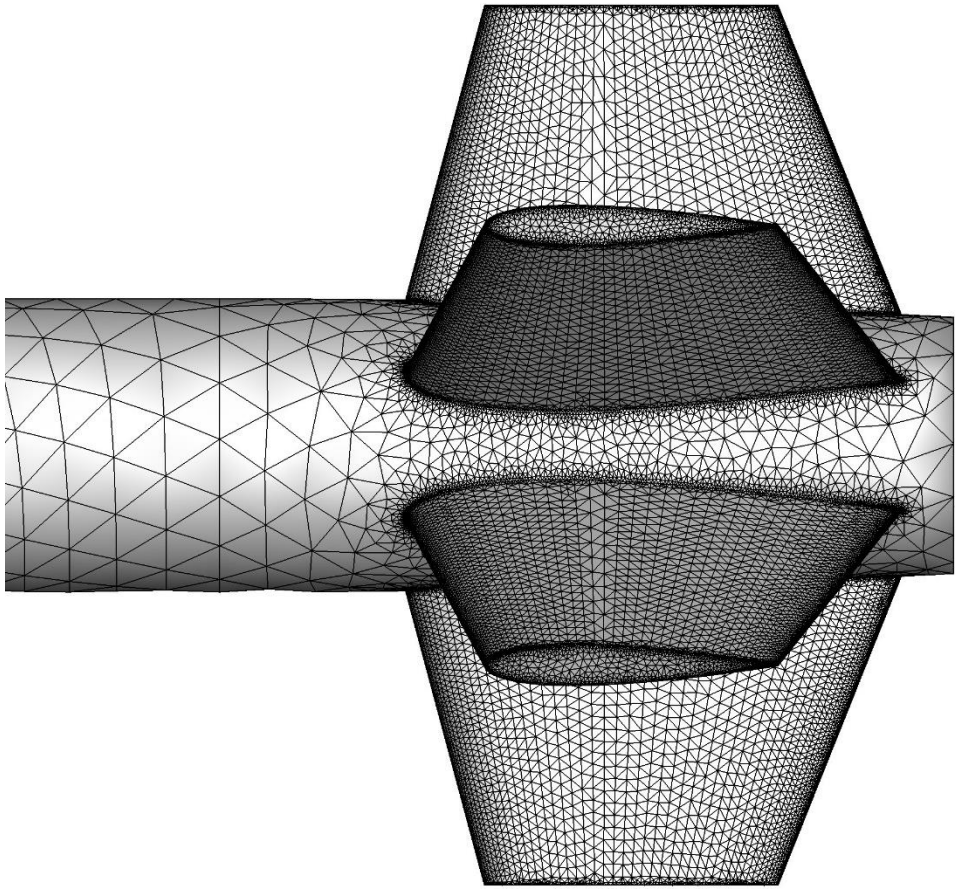
Very fine

표면격자 생성 모듈(Netgen)(계속)

Grading – 0 ~ 1 값, 인접한 두 격자의 크기 변화 설정



Grading 0.1

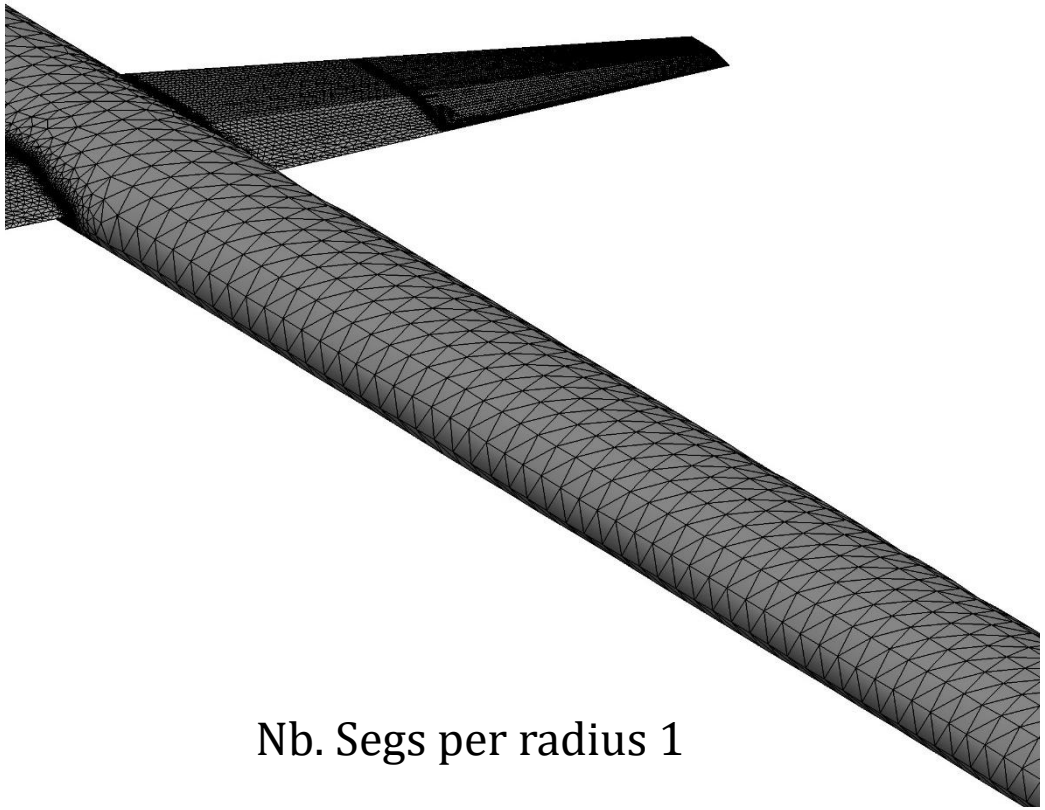


Grading 0.9

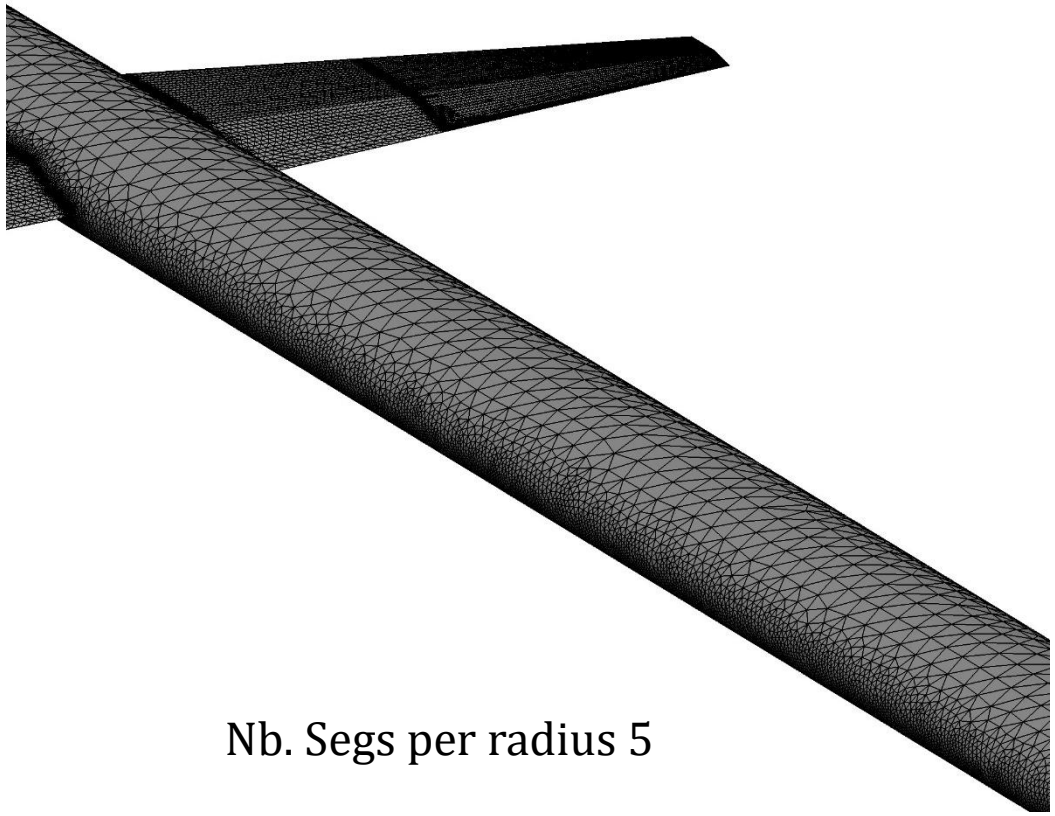
핵심 요소기술 소개

표면격자 생성 모듈(Netgen)(계속)

Nb. Segs per radius – 곡률에 따른 격자 밀집도 설정



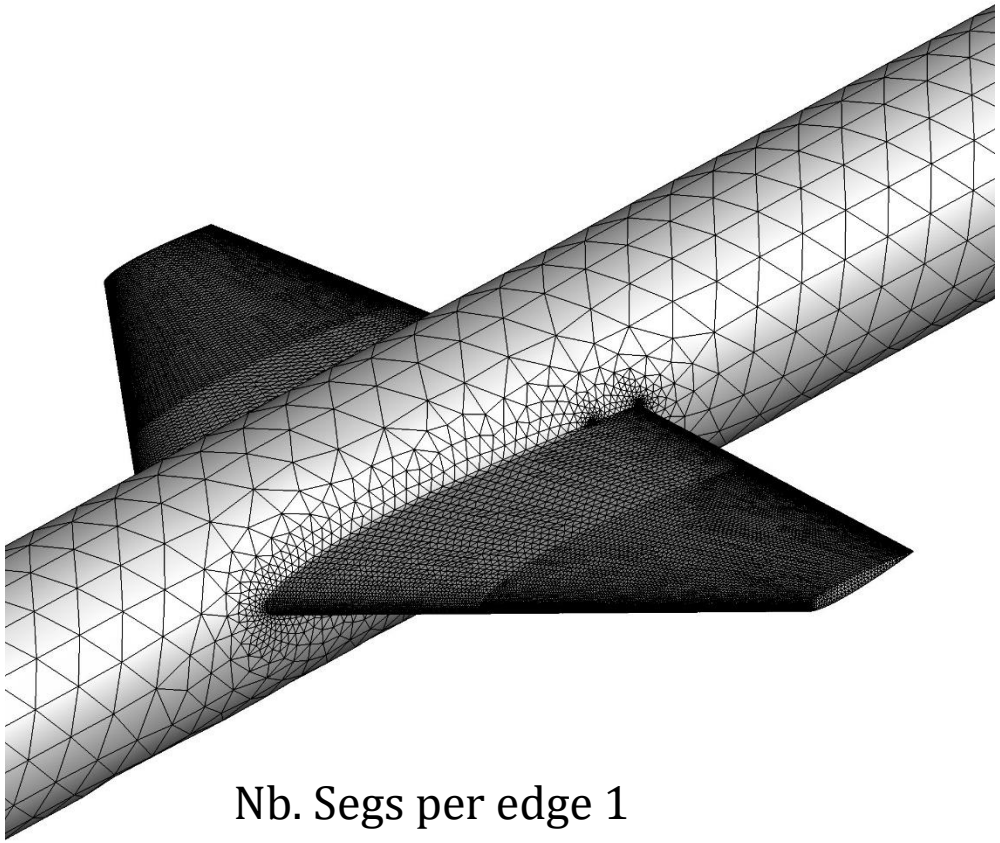
Nb. Segs per radius 1



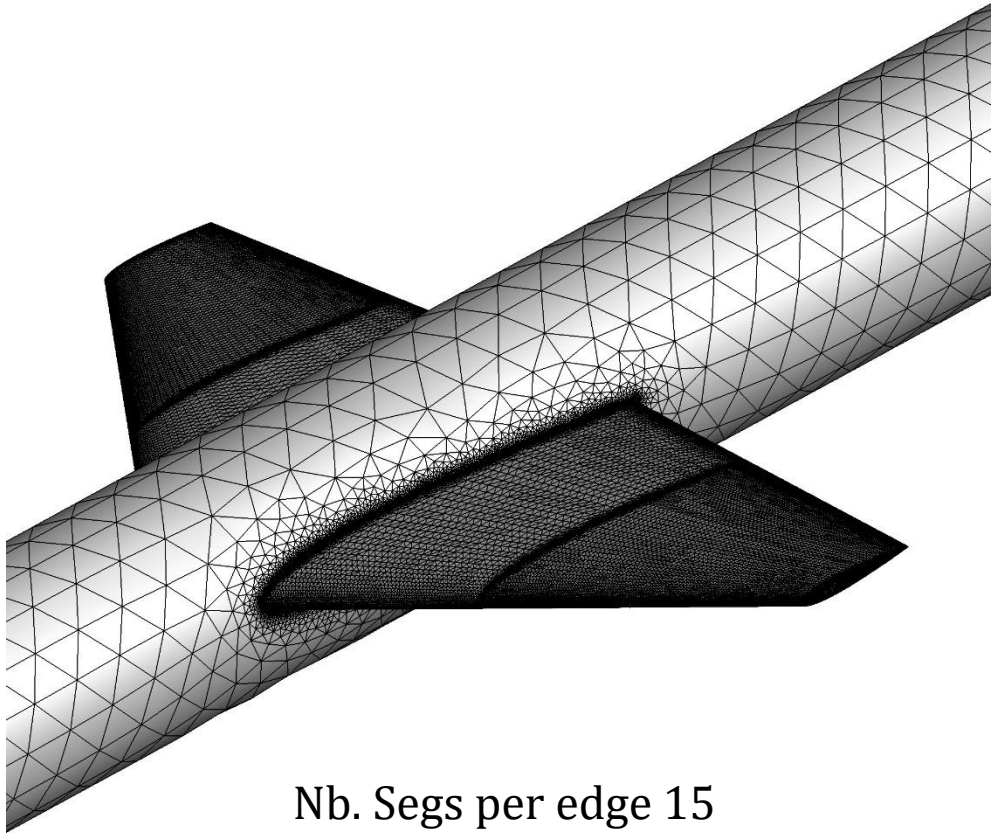
Nb. Segs per radius 5

표면격자 생성 모듈(Netgen)(계속)

Nb. Segs per edge – face edge의 격자 밀집도 설정



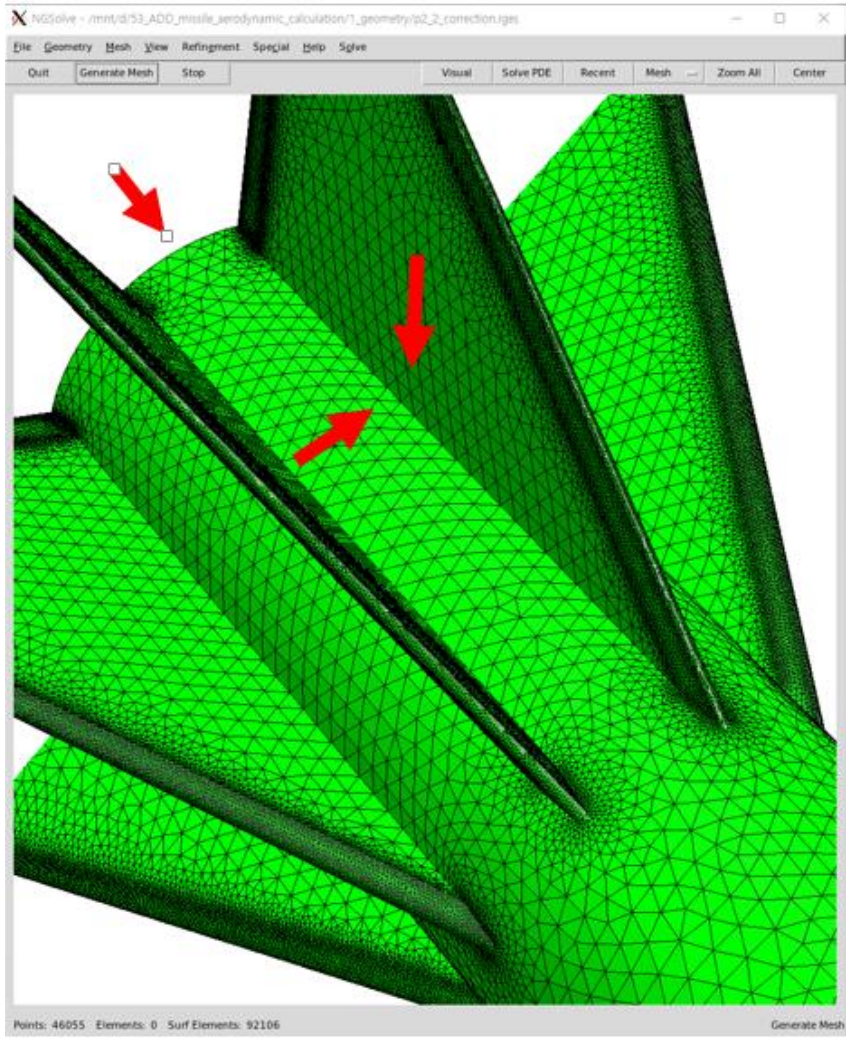
Nb. Segs per edge 1



Nb. Segs per edge 15

핵심 요소기술 소개

표면격자 생성 모듈(Netgen)(계속)



Netgen 격자의 문제점

Fin, Protuberance, Body 형상 STEP파일 불러오기

↓

필요한 Edge 또는 Face의 Local refinement를 위해 형상 Explode
(Solid > Face > Edge 순으로 Explode)

↓

Fin, Protuberance, Body 형상 Fuse

↓

Explode된 Face나 Edge 중 Local refinement에 필요한
Face와 Edge만 따로 분류

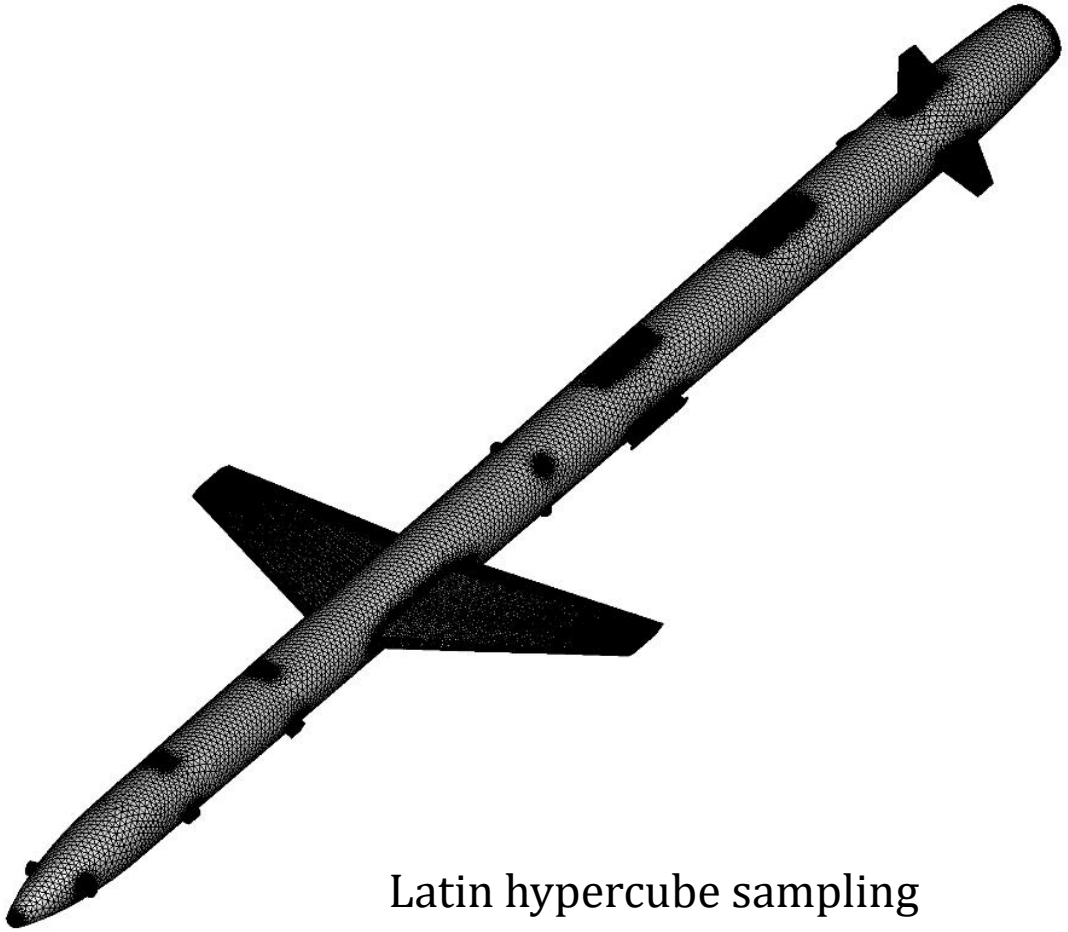
↓

설정된 Mesh parameter와 Local refinement를 적용해서 격자 생성

격자 개선을 위한 절차

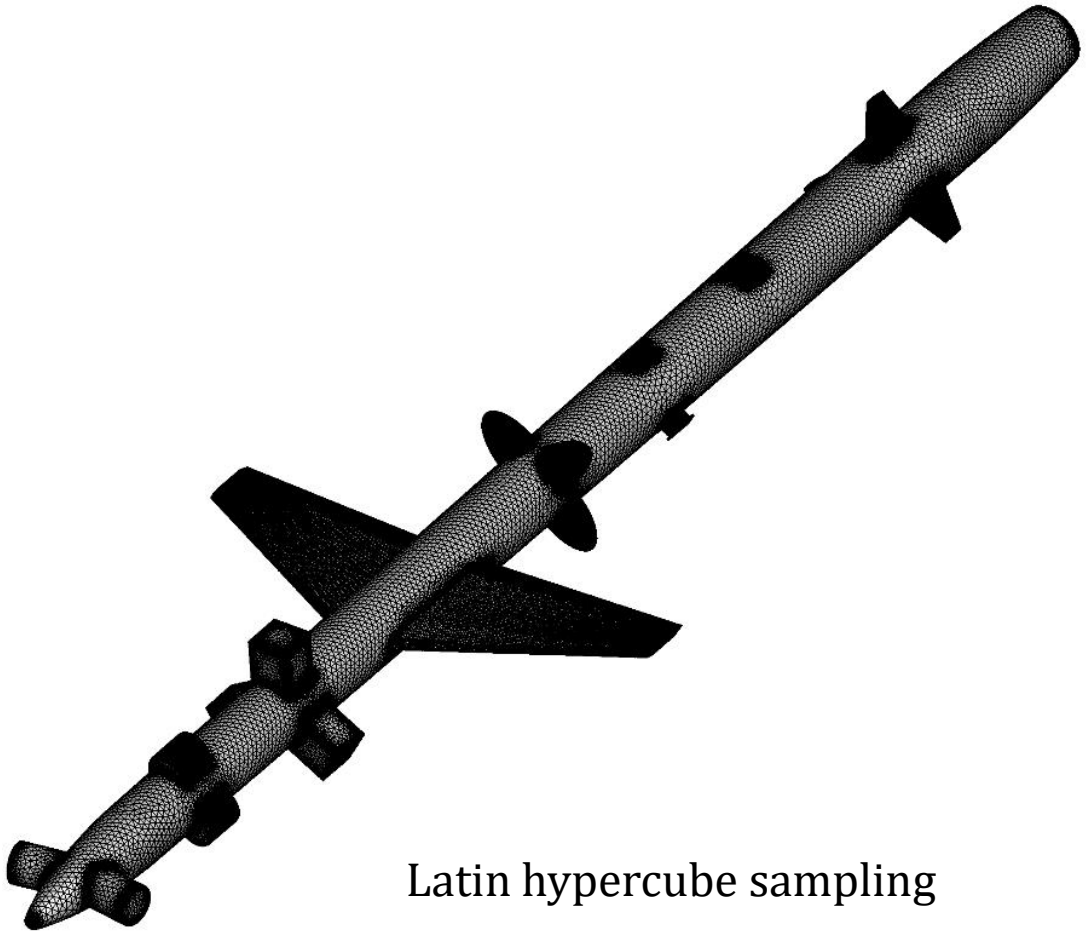
핵심 요소기술 소개

표면격자 생성 모듈(Netgen)(계속)



Latin hypercube sampling

표면격자 생성 #1

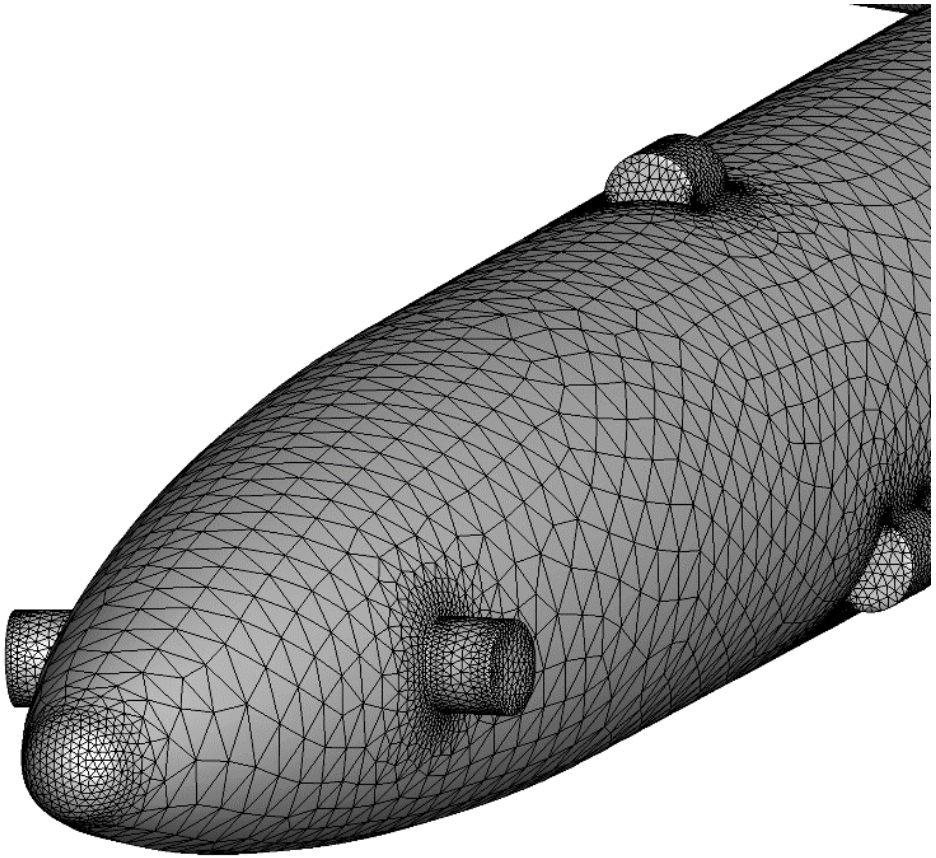


Latin hypercube sampling

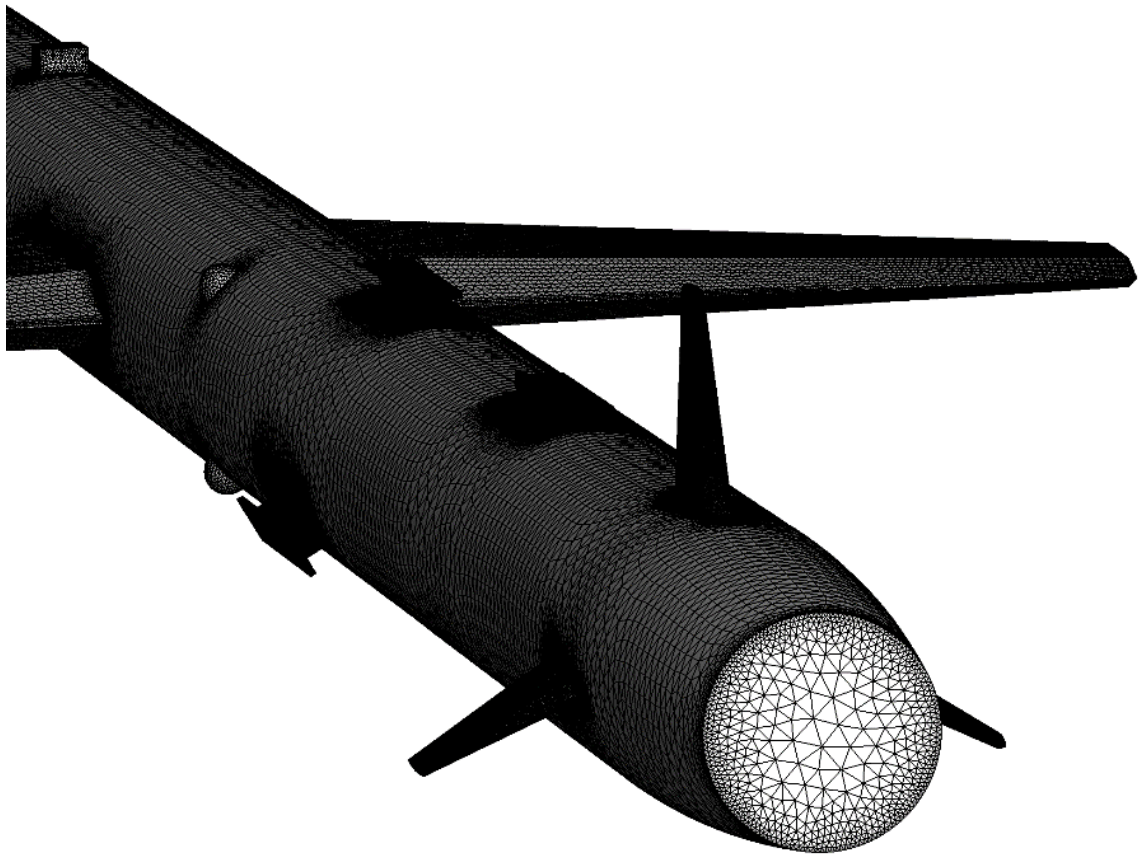
표면격자 생성 #2

핵심 요소기술 소개

표면격자 생성 모듈(Netgen)(계속)



Nose Part

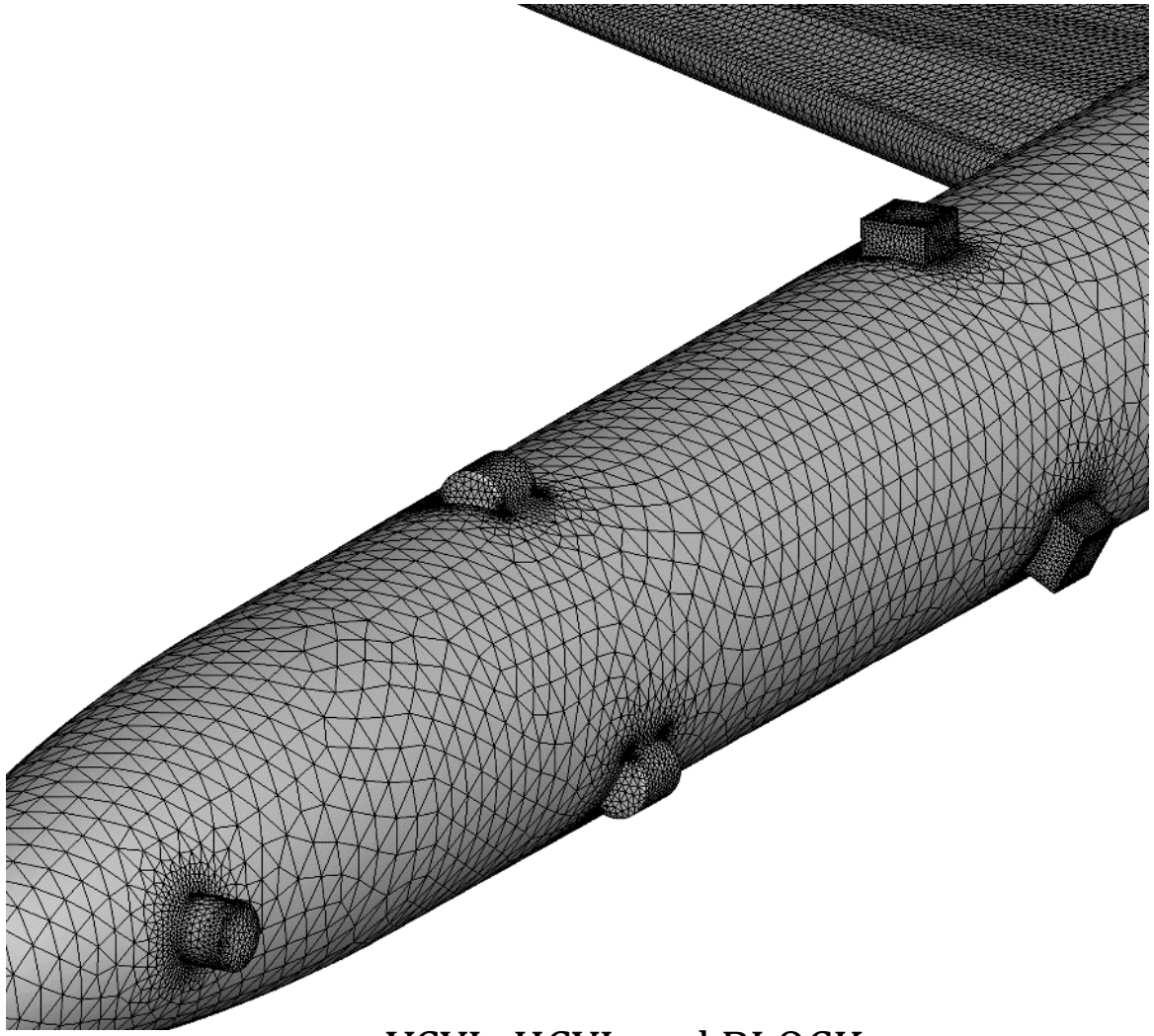


Afterbody Part

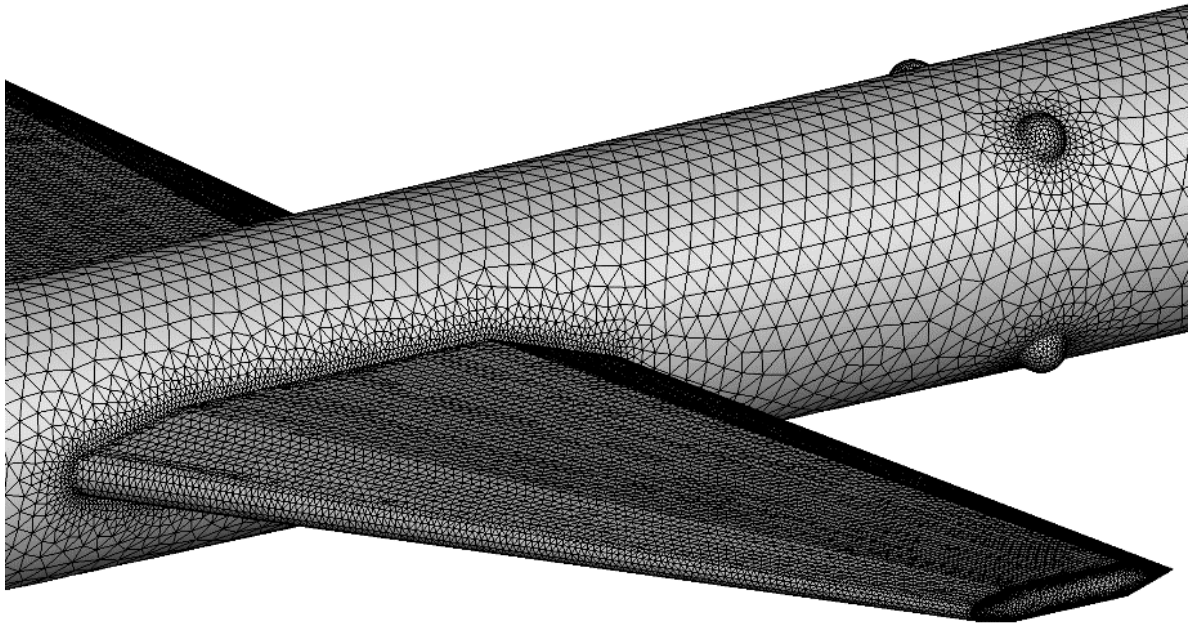
핵심 요소기술 소개

NEXTfoam open source CFD consulting

표면격자 생성 모듈(Netgen)(계속)



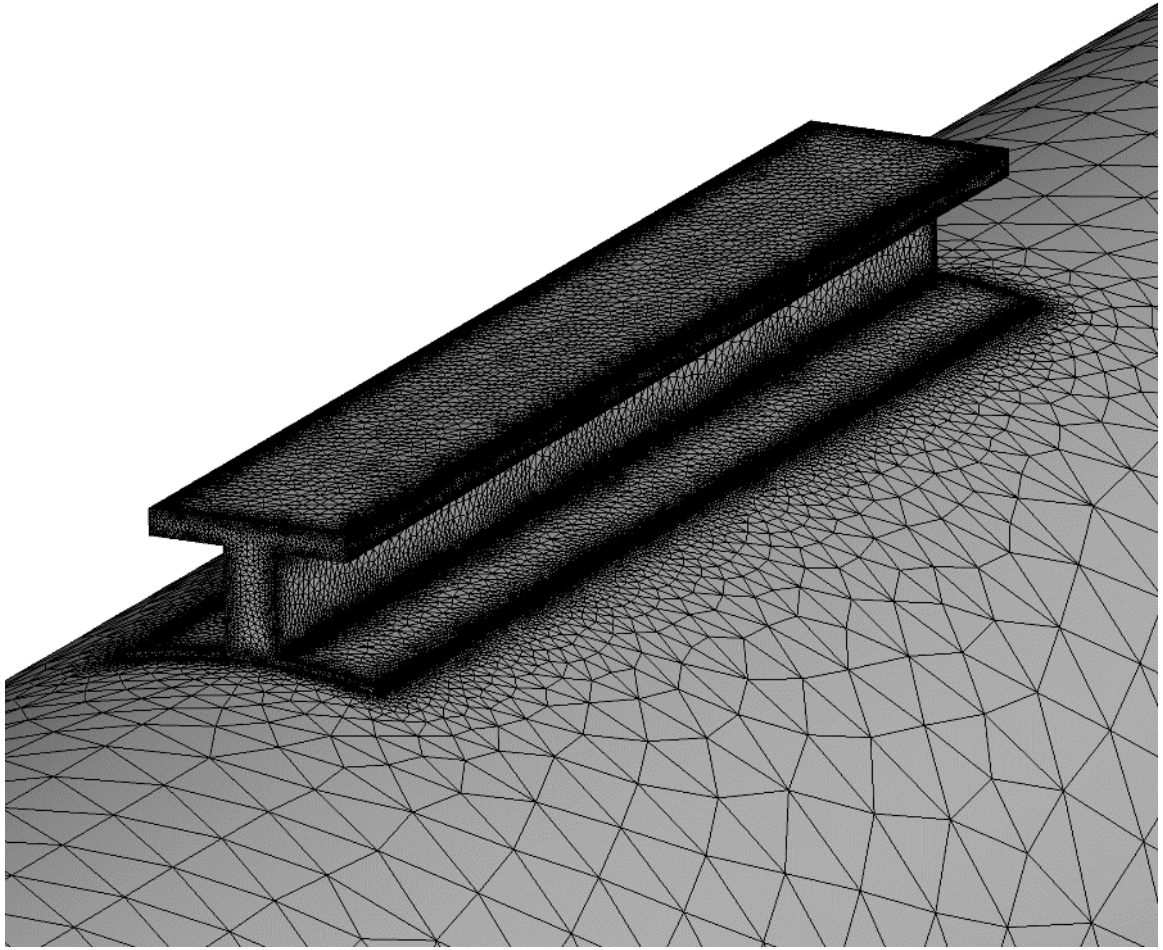
VCYL, HCYL and BLOCK



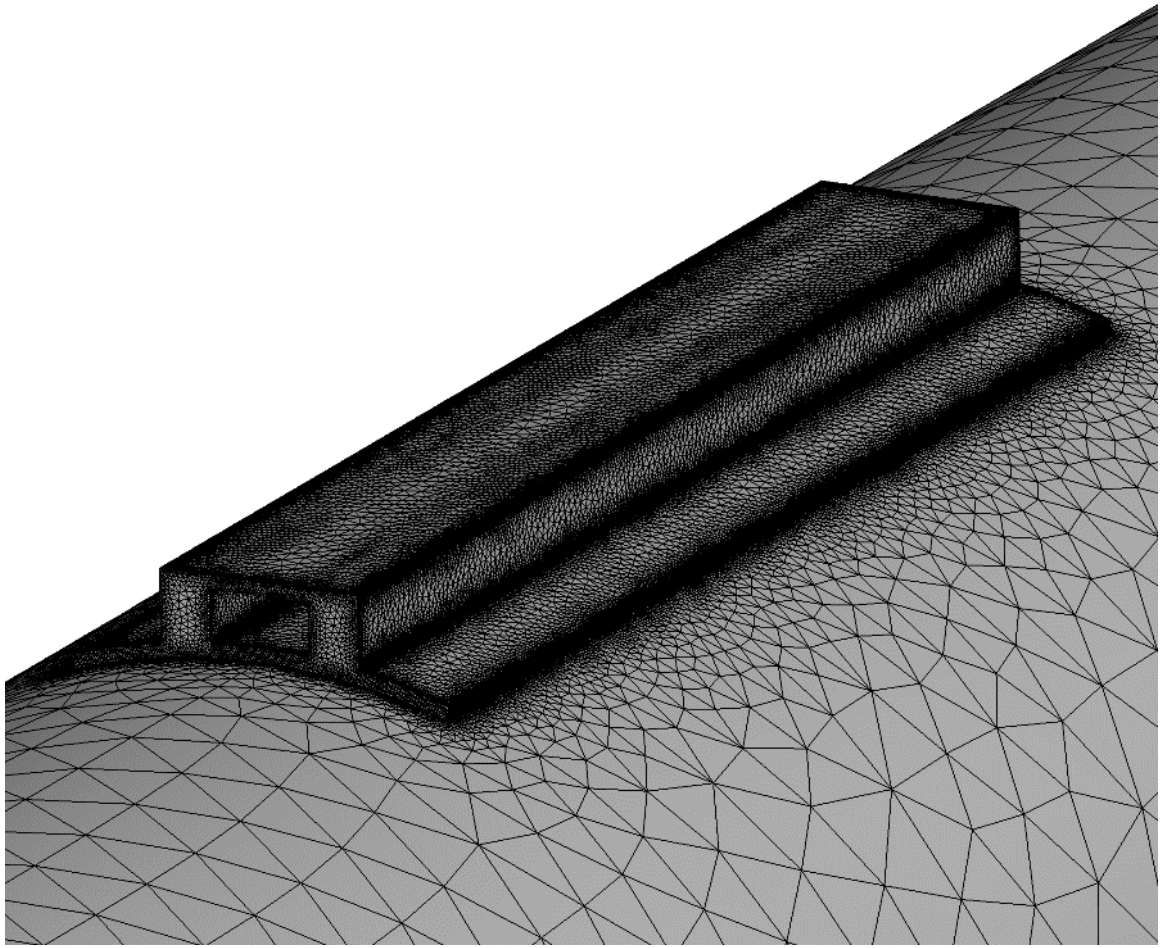
FIN and FAIRING

핵심 요소기술 소개

표면격자 생성 모듈(Netgen)(계속)



LAUNCH SHOE



LAUNCH LUG

핵심 요소기술 소개

NEXTfoam open source CFD consulting

격자계 해석자(TSLAeroFoam)

□ OpenFOAM을 기반으로 개발한 density based coupled 압축성 공력해석자

□ 내재적 시간 적분을 위해 Implicit LU-SGS (Lower Upper Symmetric Gauss Seidel) 기법 적용

□ 점성 플럭스 자코비안 처리를 위해 TSL (Thin Shear Layer) approximation 적용

□ 공간 2차 정확도 확보 및 충격파 포착 능력 향상을 위해 Roe, AUSM+ 및 AUSM+Up 기법 적용

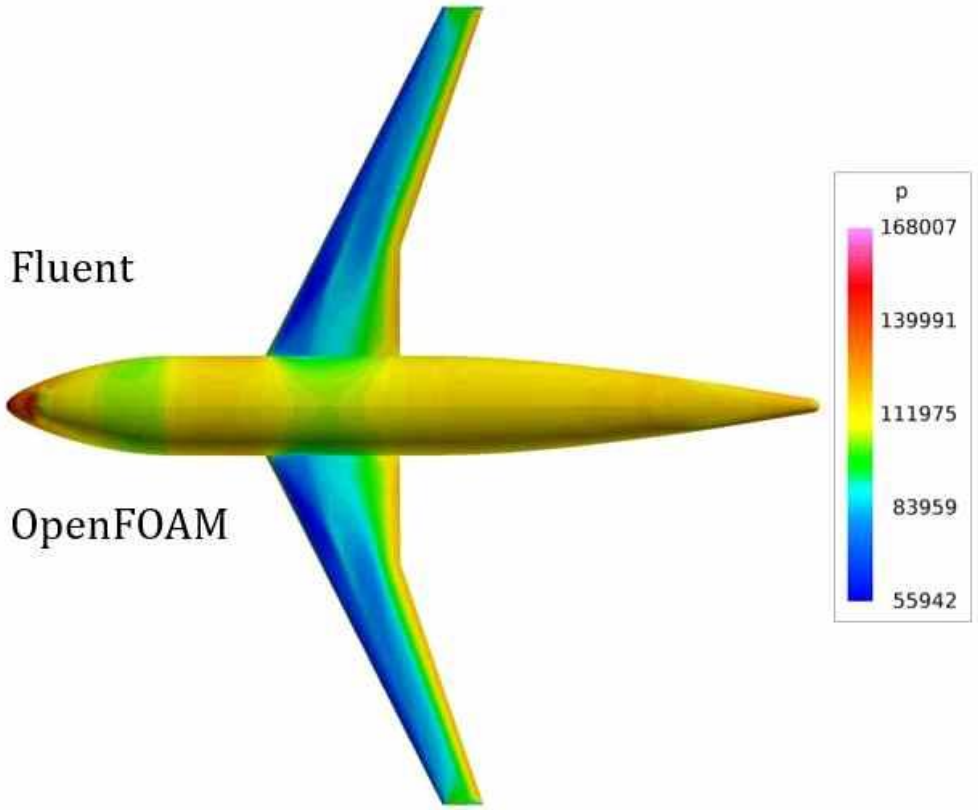
□ Riemann invariant 경계조건 개발

□ 오픈소스 난류 모델 라이브러리 활용으로 kω-SST 및 SA 등 다양한 난류 모델 지원

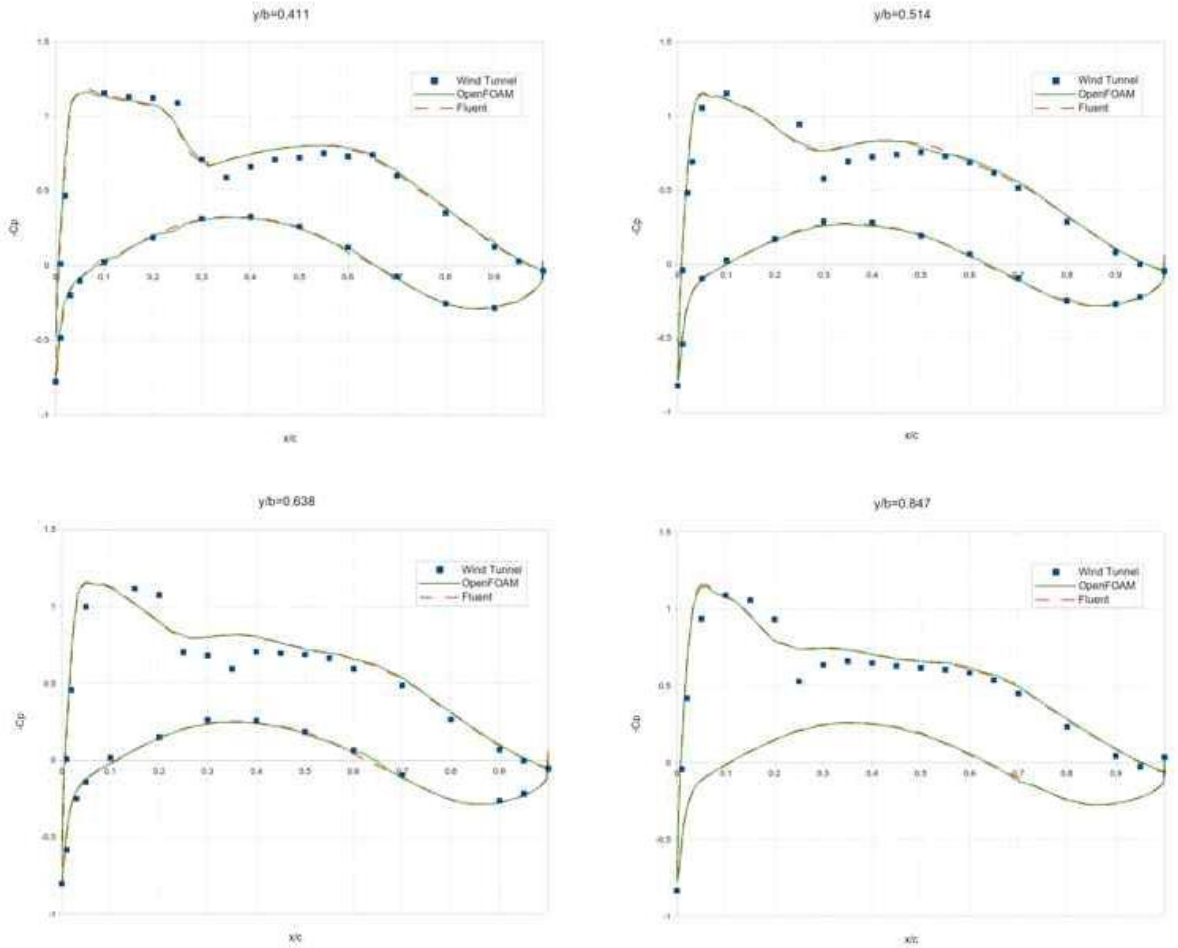
핵심 요소기술 소개

격자계 해석자(TSLAeroFoam)(계속)

천음속 3차원 항공기(Ma=0.75, AOA=0.49°)



압력 분포 비교



위치 별 압력 분포 비교

핵심 요소기술 소개

NEXTfoam open source CFD consulting

질점계 해석자(FAMUS)

□ 격자없이 질점계로 해석 영역을 생성하는 무격자 방식 적용

□ 질점계 적용으로 인해 복잡한 형상 및 물체의 이동을 포함하는 해석영역 생성 용이

□ 격자계 기반의 FVM과 동일한 수준의 보존성을 갖추기 위해 Geometric Conservation Law 충족

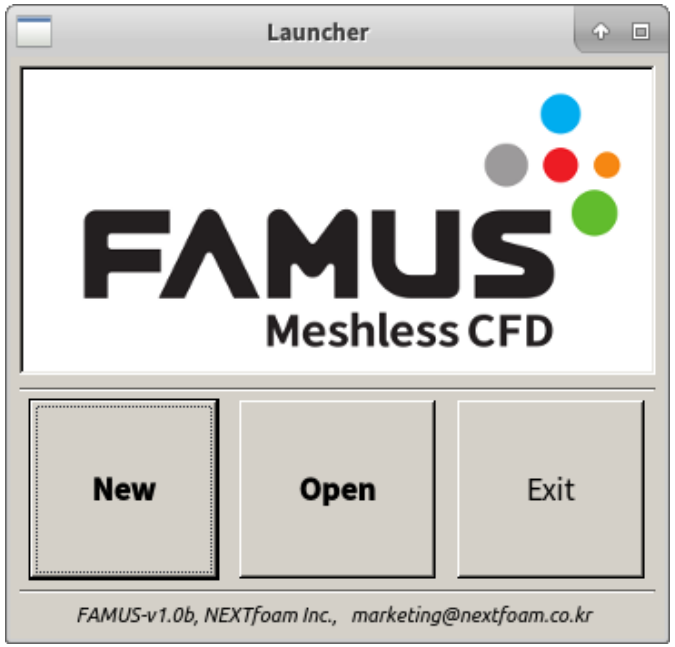
□ 내재적 시간 적분을 위해 Implicit LU-SGS (Lower Upper Symmetric Gauss Seidel) 기법 적용

□ 대류항 플럭스 계산기법 AUSMPW+를 무격자 기법에 적용

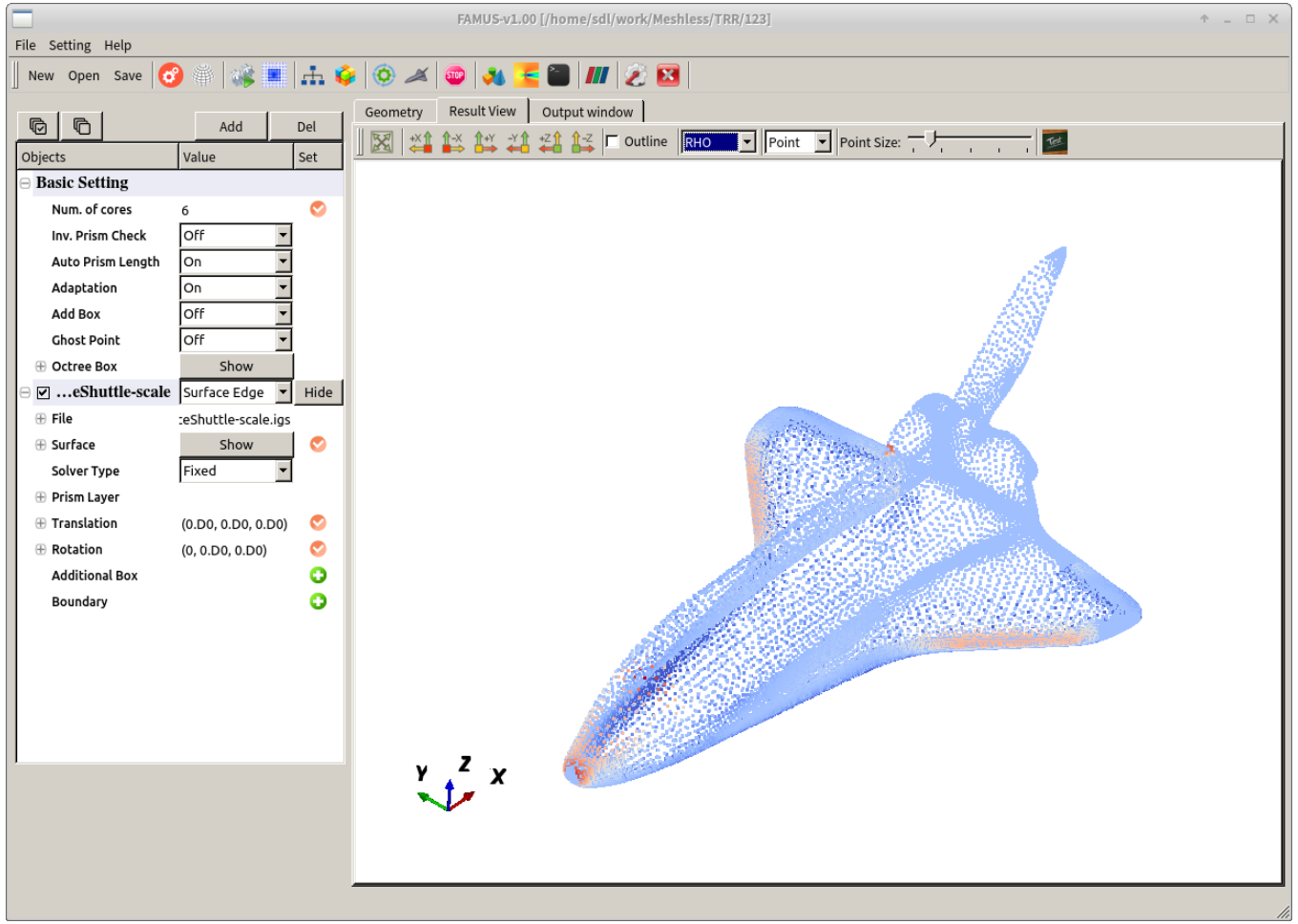
□ 공간 재구성 기법을 위해 안정성이 높은 다차원 제한자(MLP) 사용

핵심 요소기술 소개

질점계 해석자(FAMUS)(계속)



FAMUS launcher

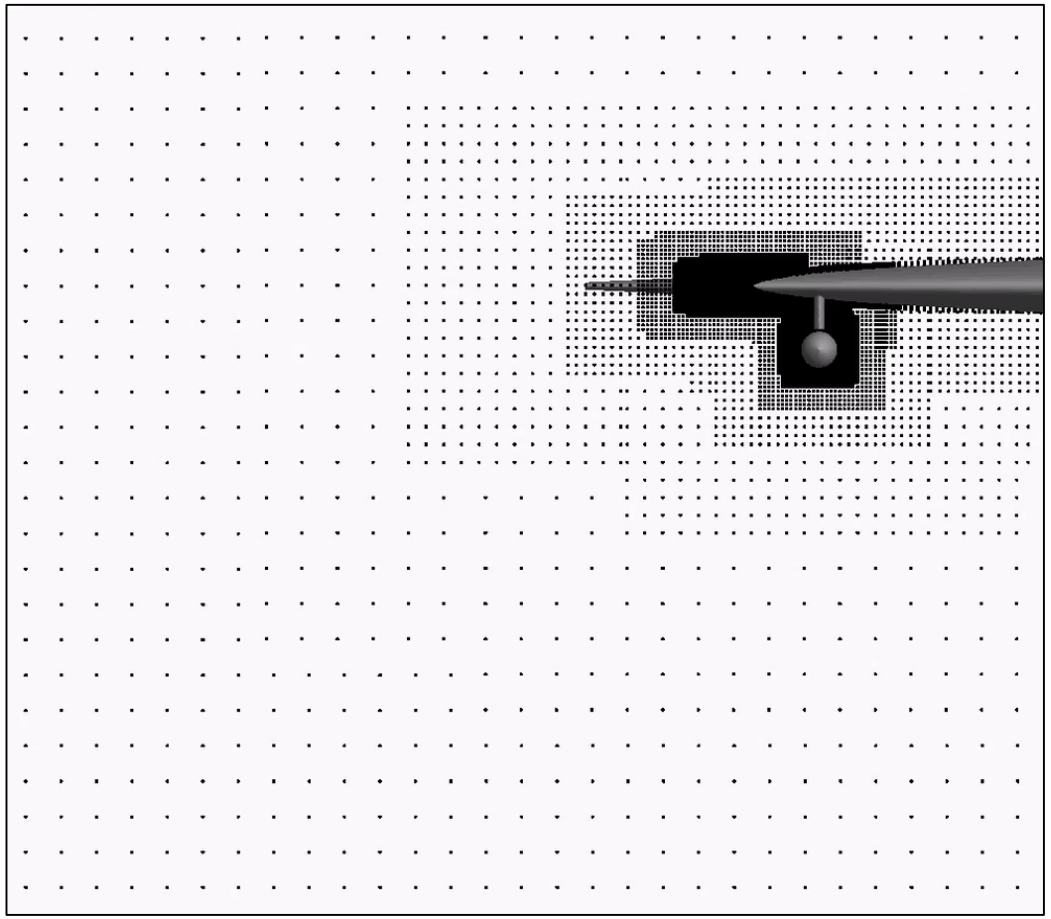


FAMUS GUI

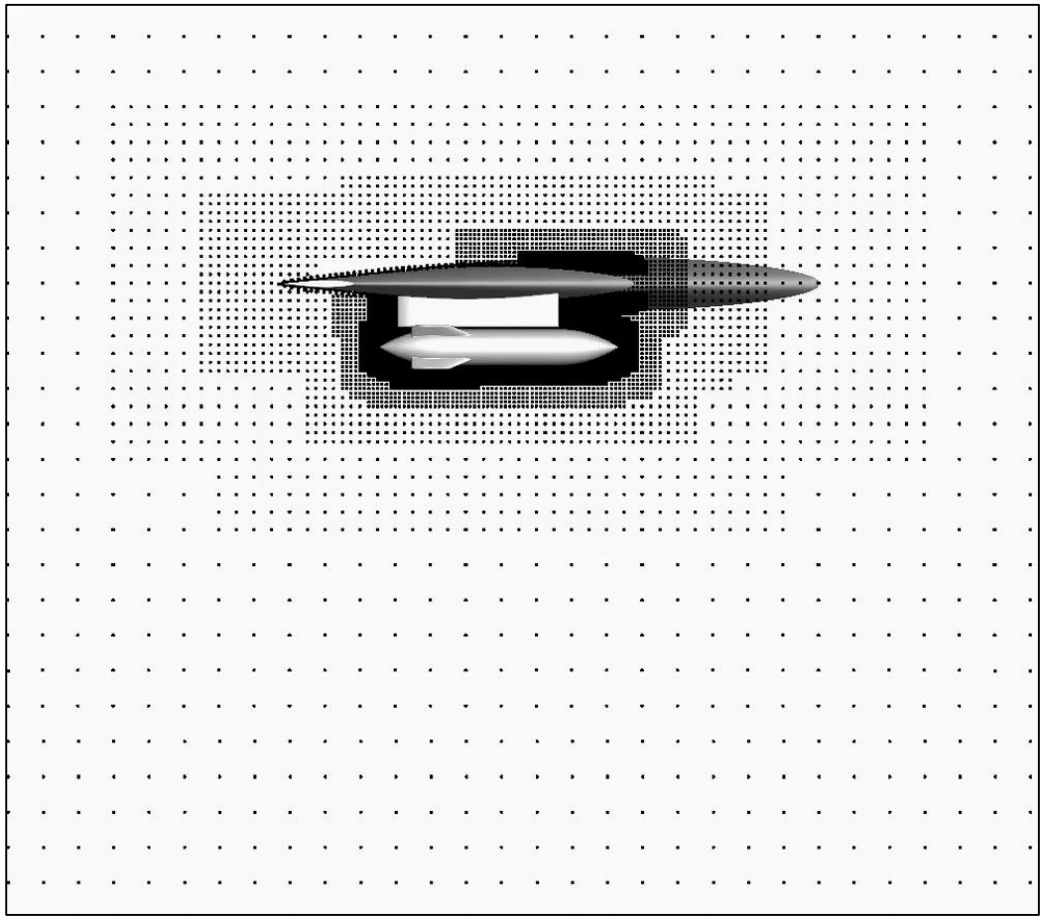
핵심 요소기술 소개

질점계 해석자(FAMUS)(계속)

EGLIN Store Separation



질점계 정면

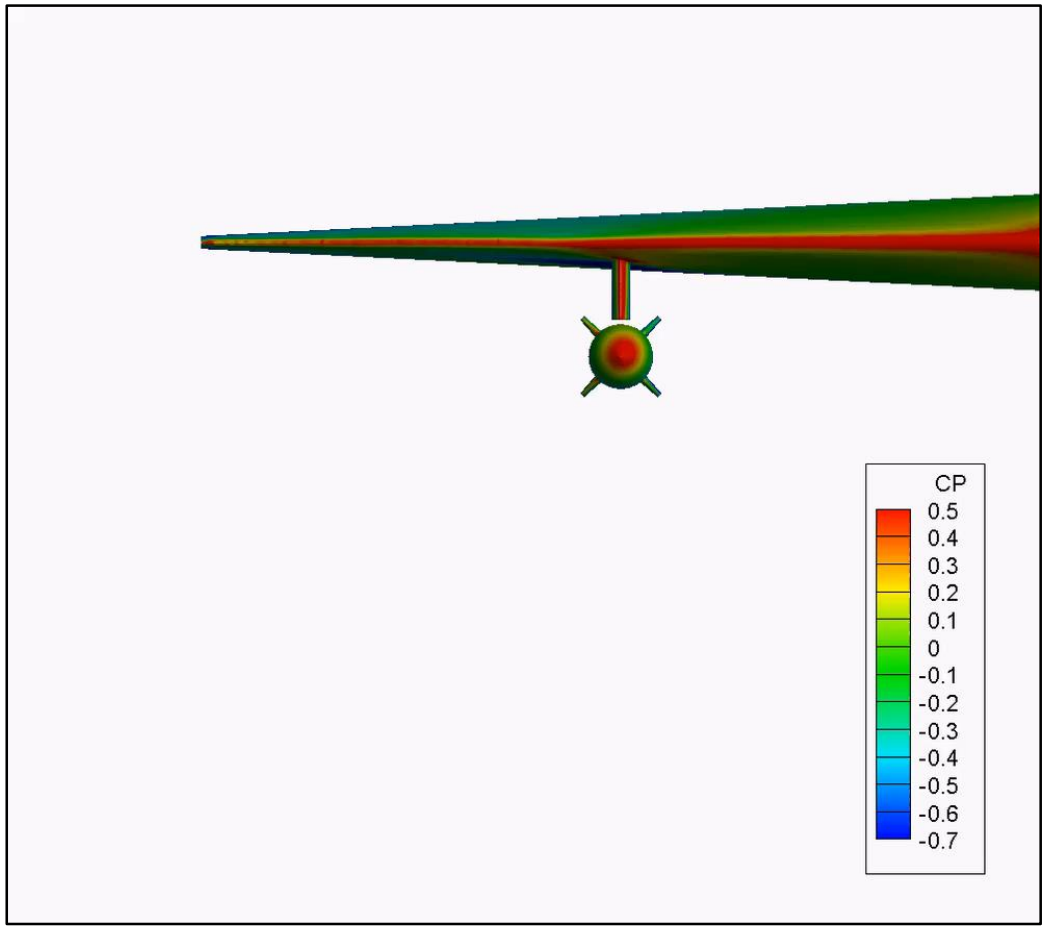


질점계 측면

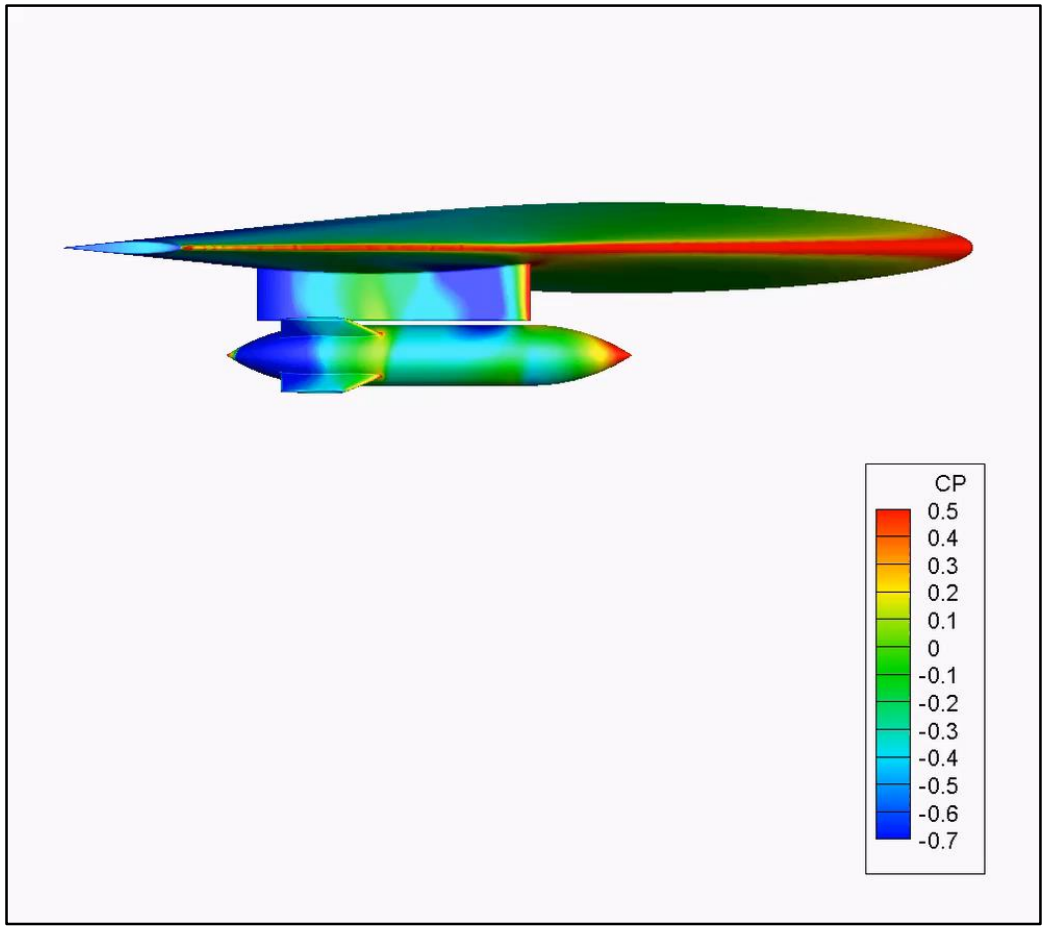
핵심 요소기술 소개

질점계 해석자(FAMUS)(계속)

EGLIN Store Separation



압력분포 정면

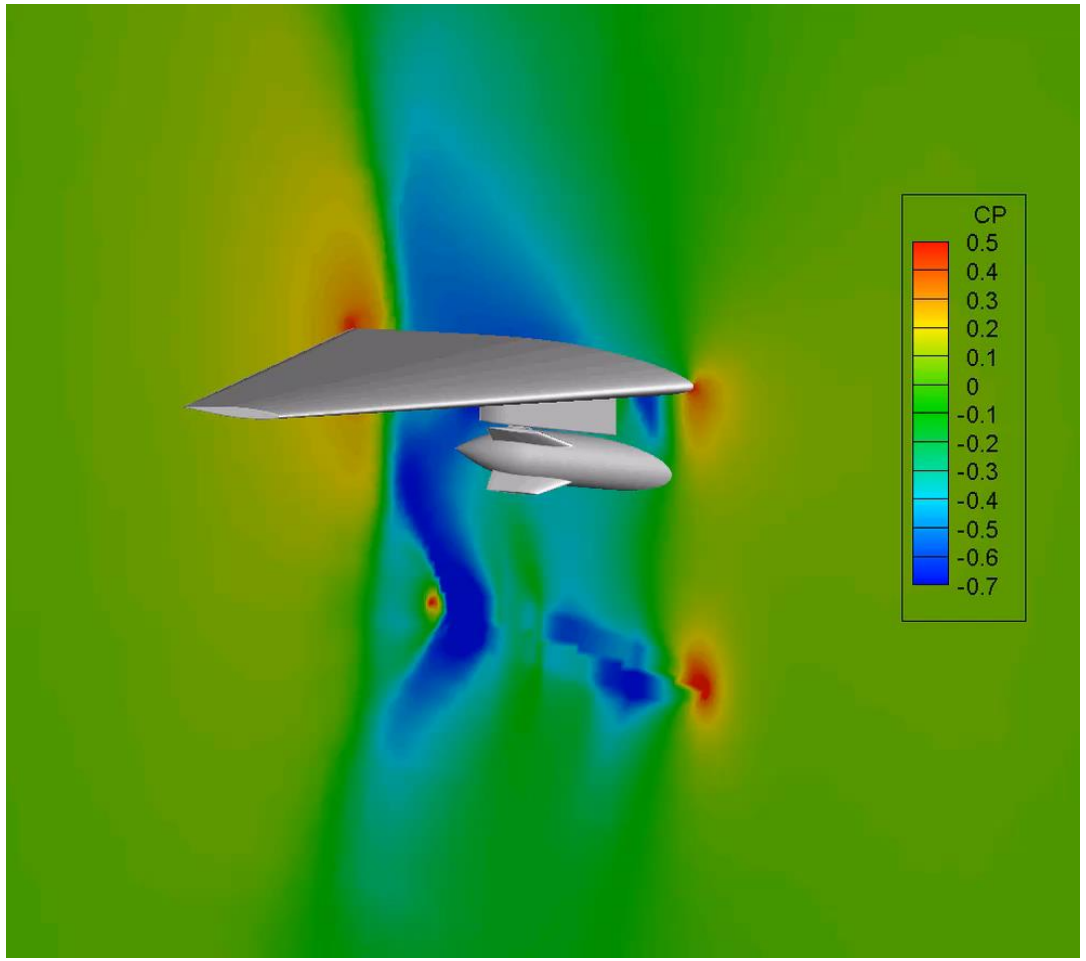


압력분포 측면

핵심 요소기술 소개

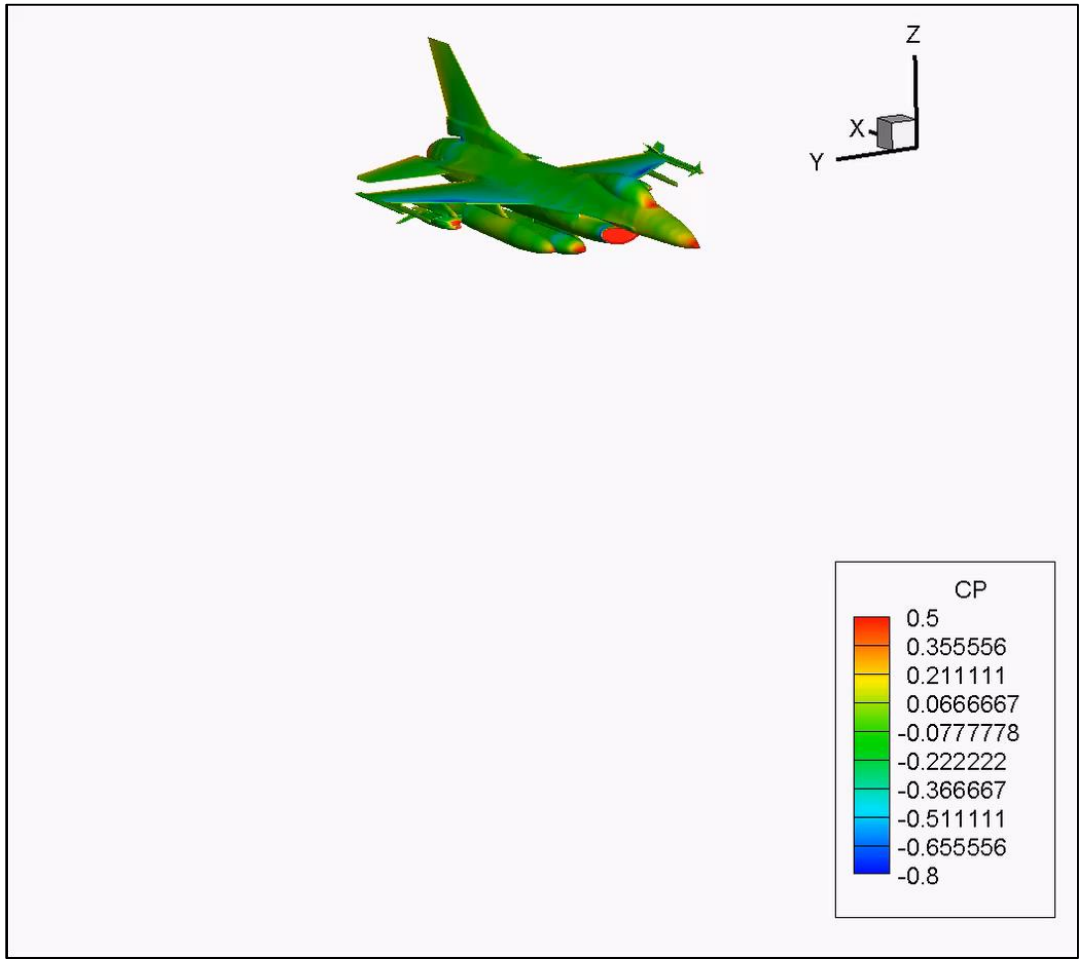
질점계 해석자(FAMUS)(계속)

EGLIN Store Separation



유동장 압력분포

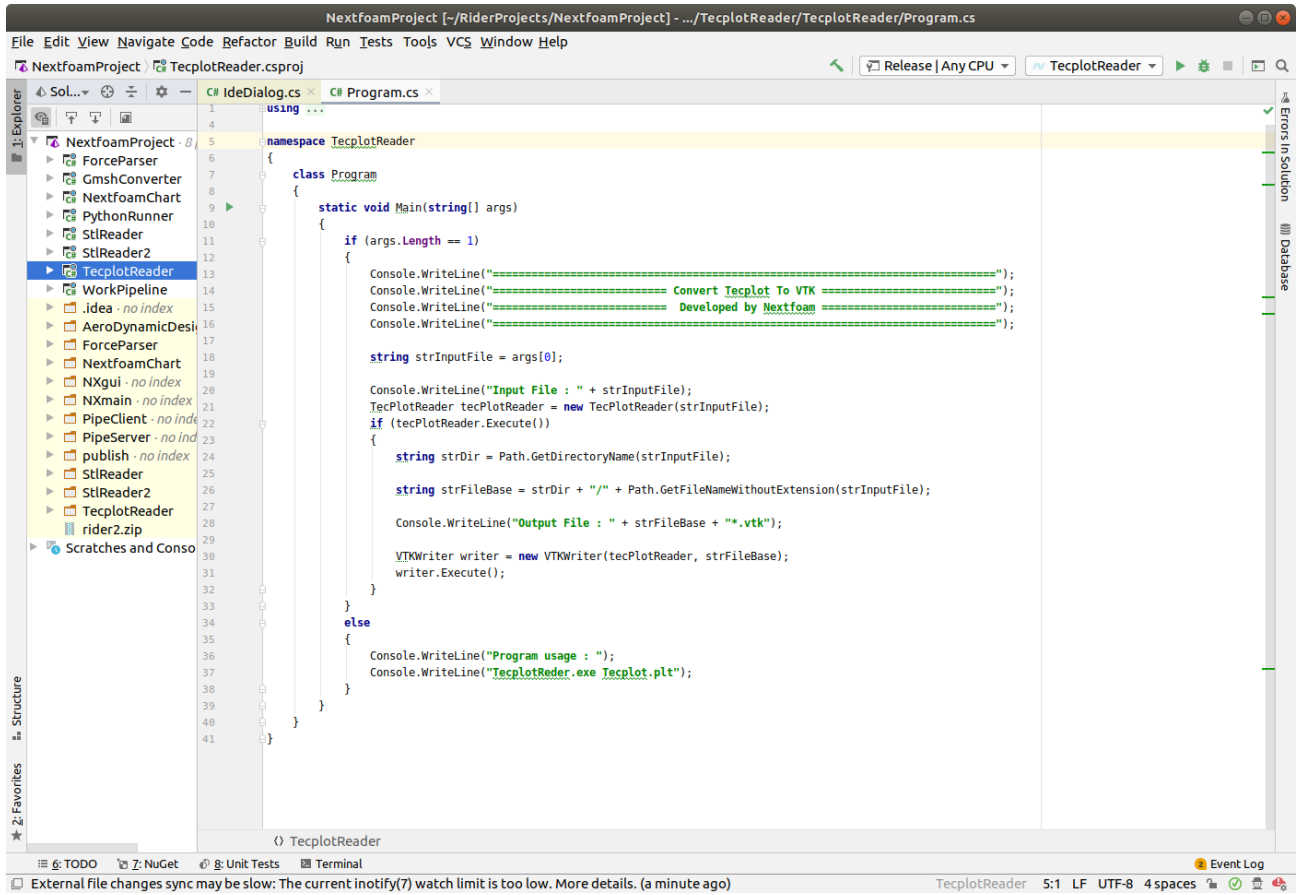
F-16 Store Separation

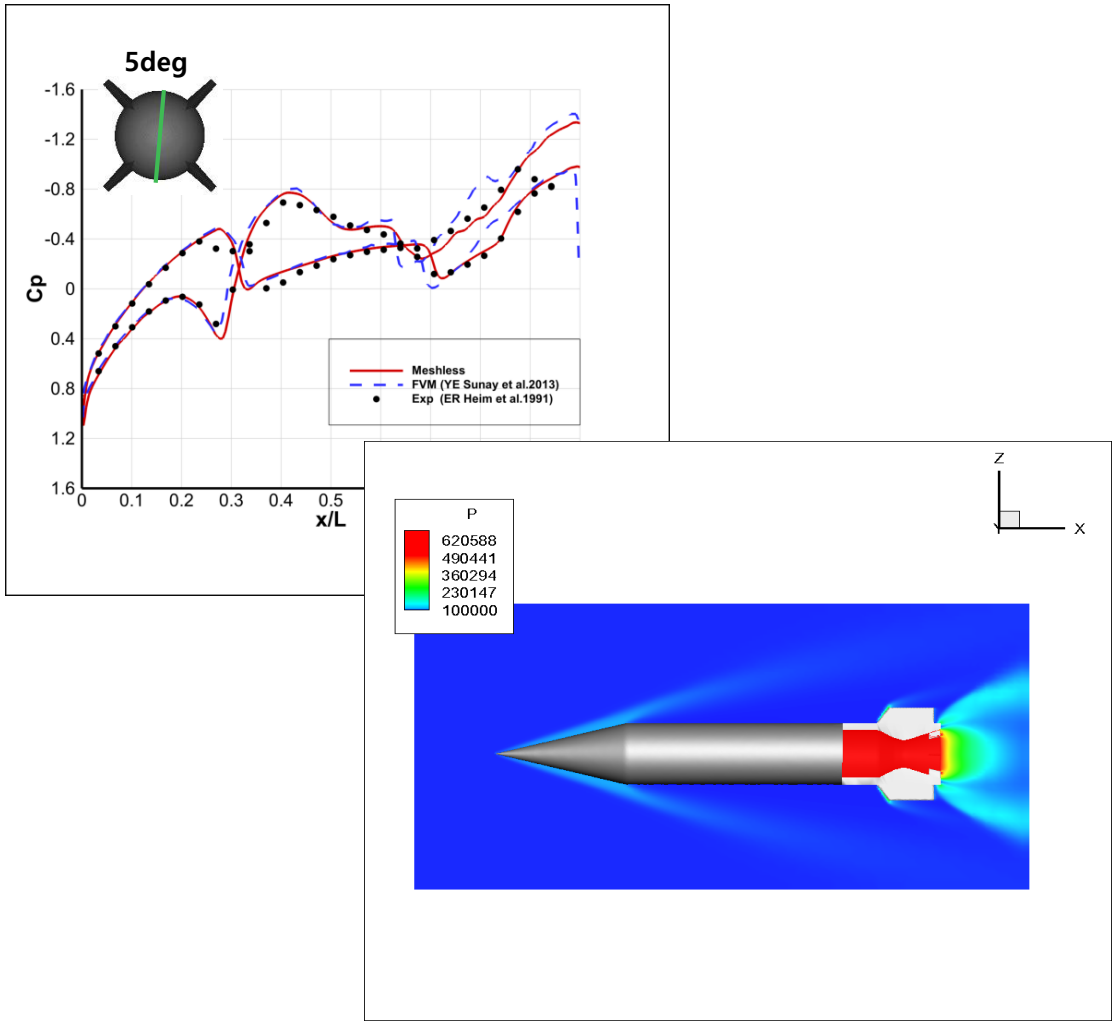


다수 무장 분리(압력분포)

핵심 요소기술 소개

후처리 자동화 및 D/B 구축(VTK & MongoDB)



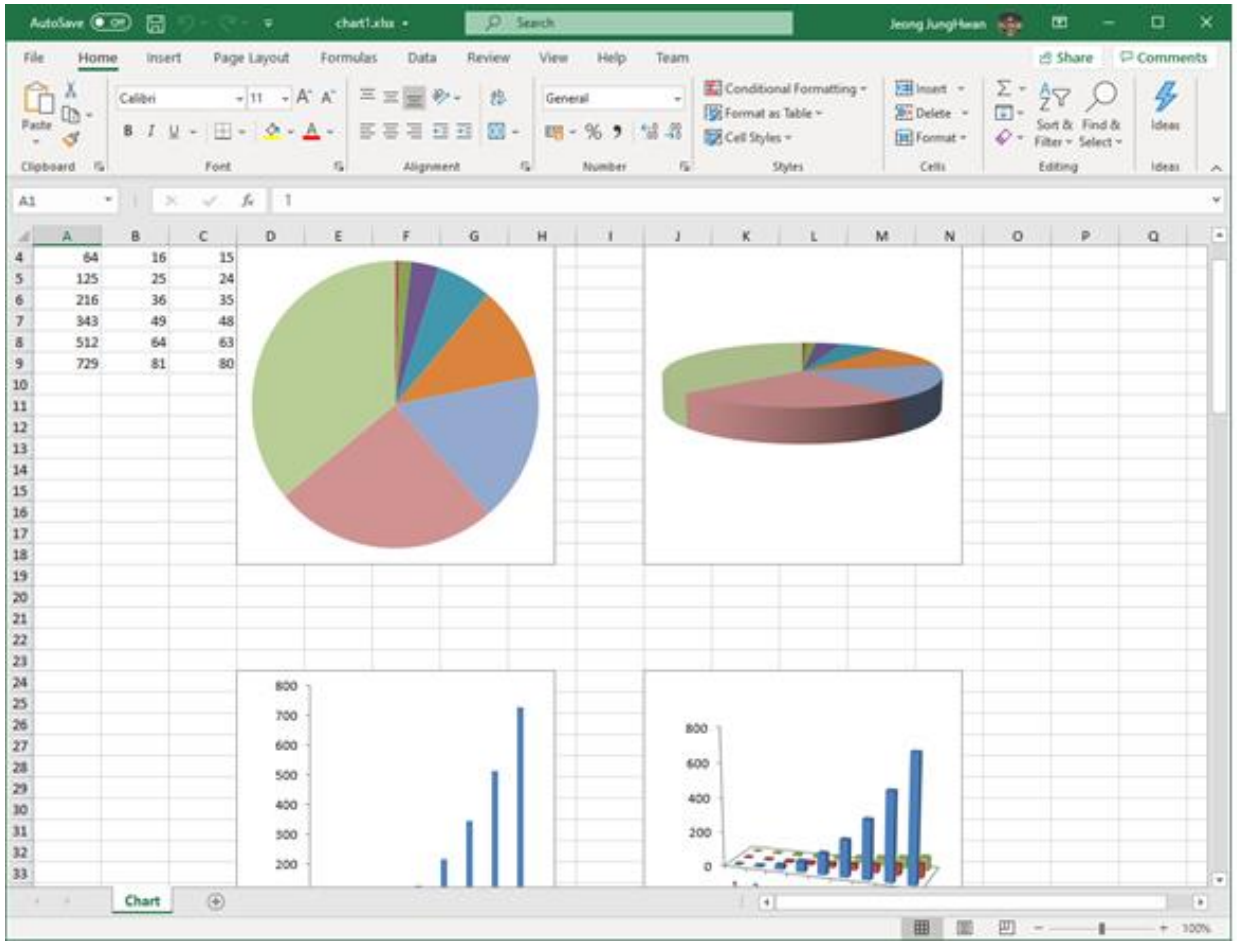


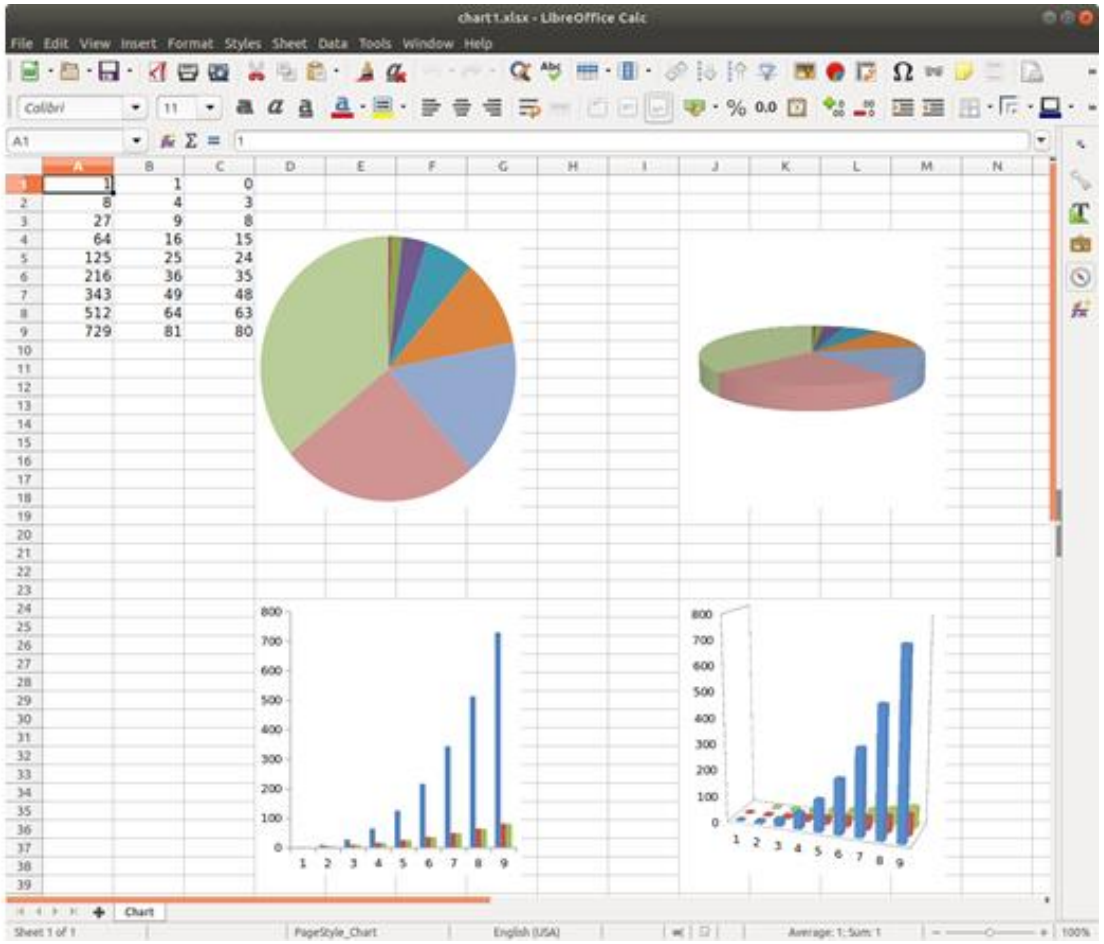
통합 포맷을 위해 개발된 VTK Converter

기 정의된 후처리 예시

핵심 요소기술 소개

후처리 자동화 및 D/B 구축(VTK & MongoDB)(계속)

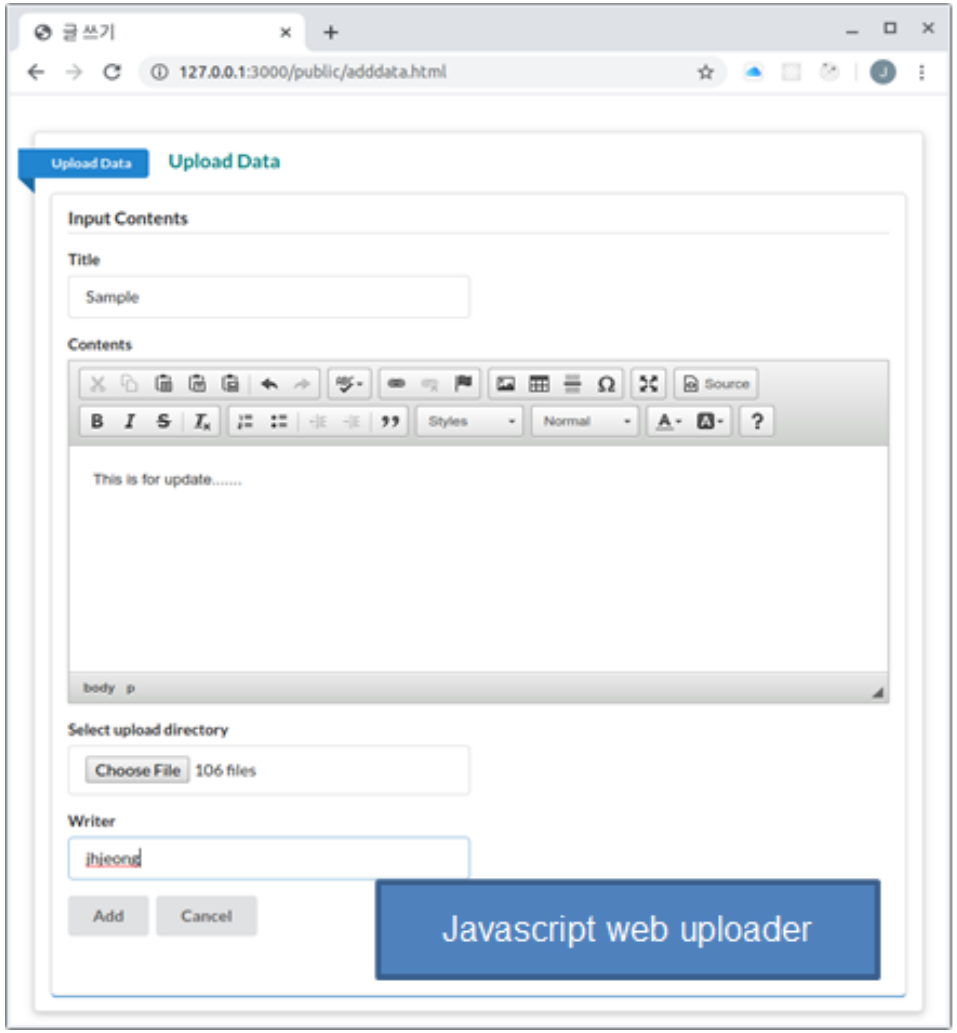


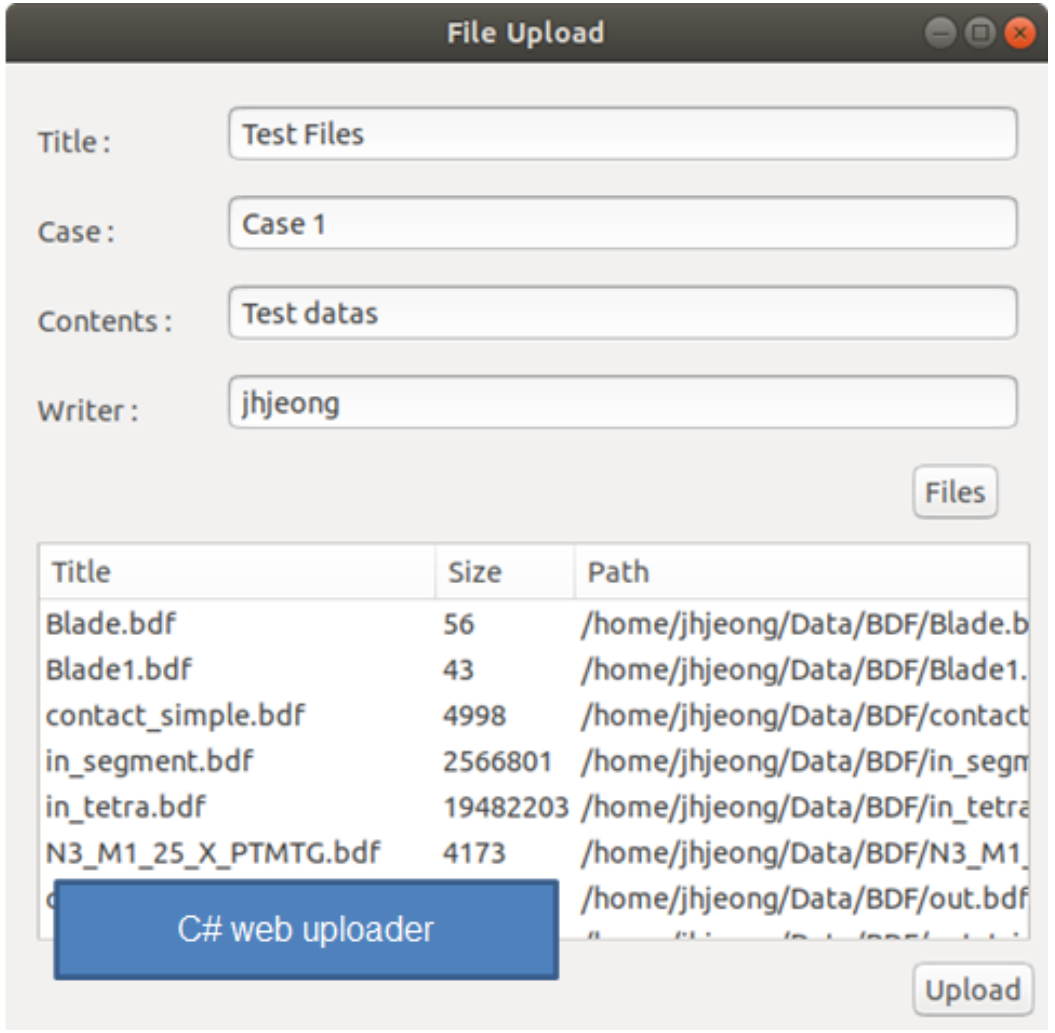


객체 핸들링을 통한 보고서 자동 생성 예시

핵심 요소기술 소개

후처리 자동화 및 D/B 구축(VTK & MongoDB)(계속)

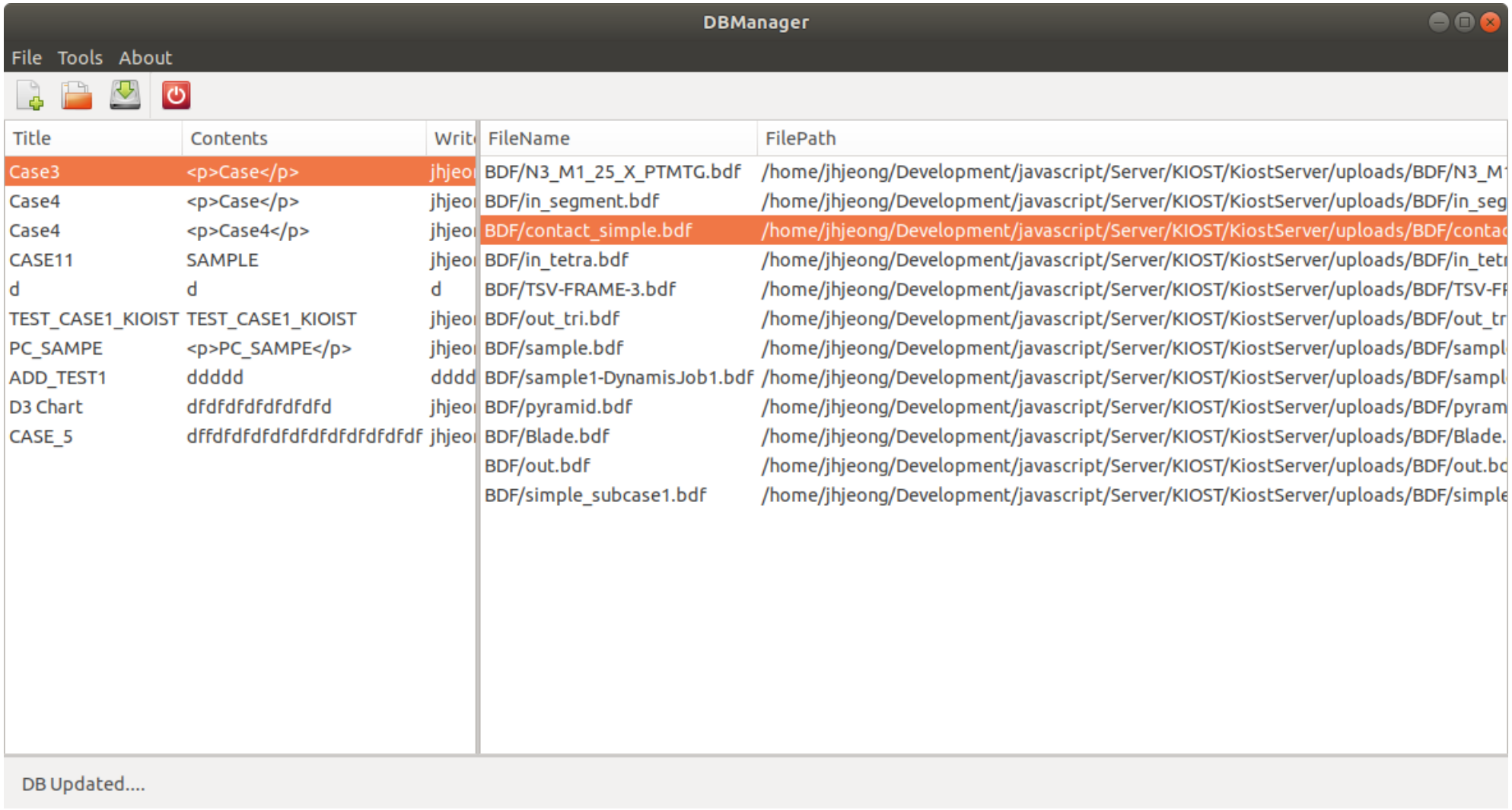




Database file uploader

핵심 요소기술 소개

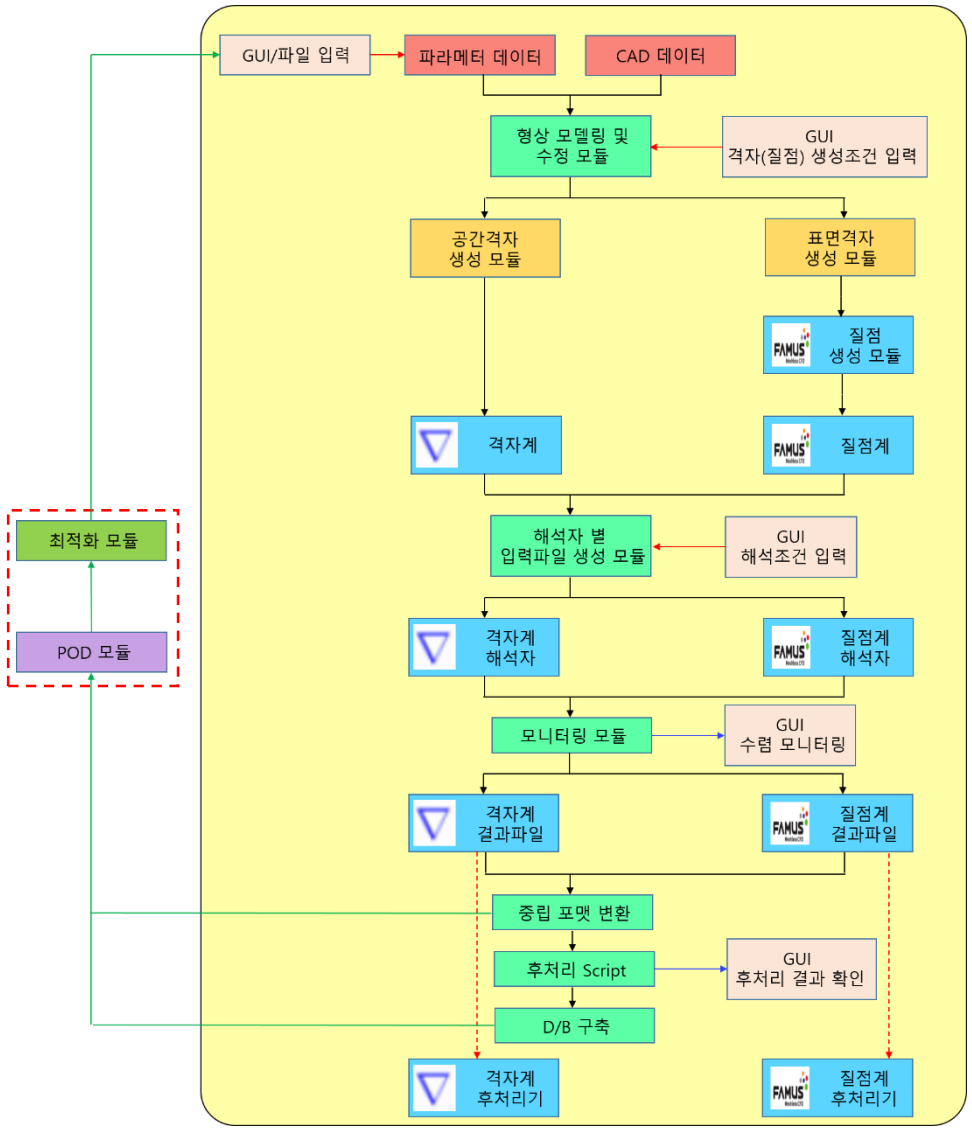
후처리 자동화 및 D/B 구축(VTK & MongoDB)(계속)



Database 조회 및 파일 다운로드를 위한 DB Manager

향후 추가 계획

최적화 모듈 및 POD 모듈 추가



최적화 모듈

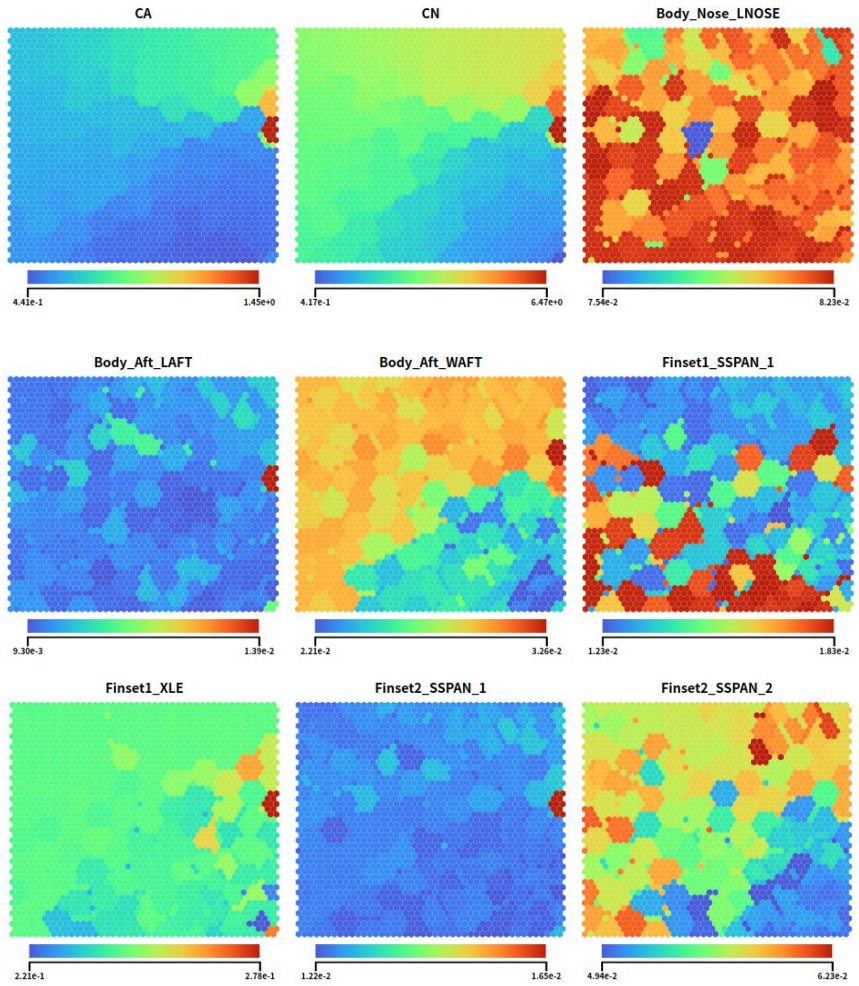
- 대체 모델(Surrogate model) : Kriging method
- 최적화 : 다목적 유전 알고리즘(MOGA)
- 데이터 마이닝 : SOM (Self Organizing Map) &
  ANOVA (Analysis of Variance)

POD (Proper Orthogonal Decomposition) 모듈

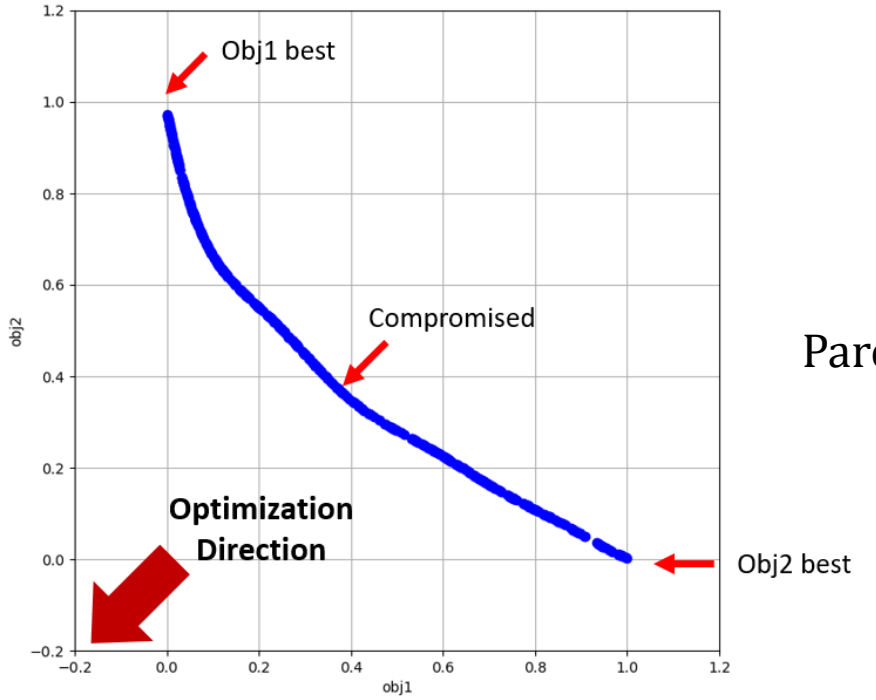
- 유동장 재구성
- 최적화 및 역설계
- 데이터 합성

향후 추가 계획

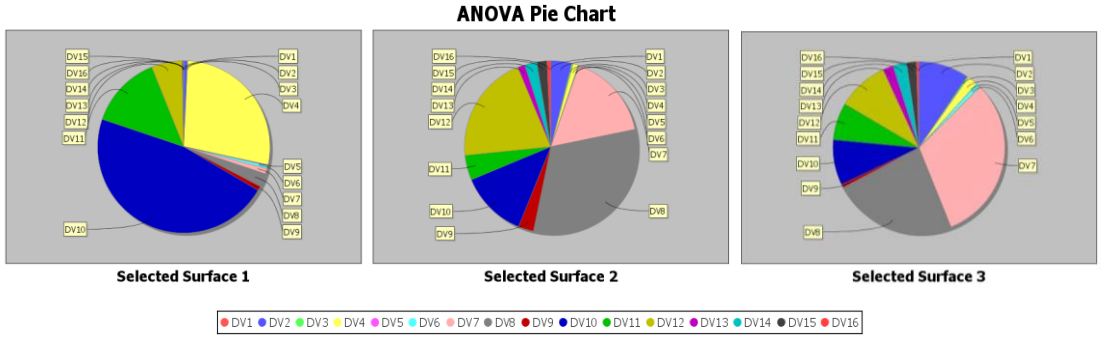
최적화 모듈



SOM 결과



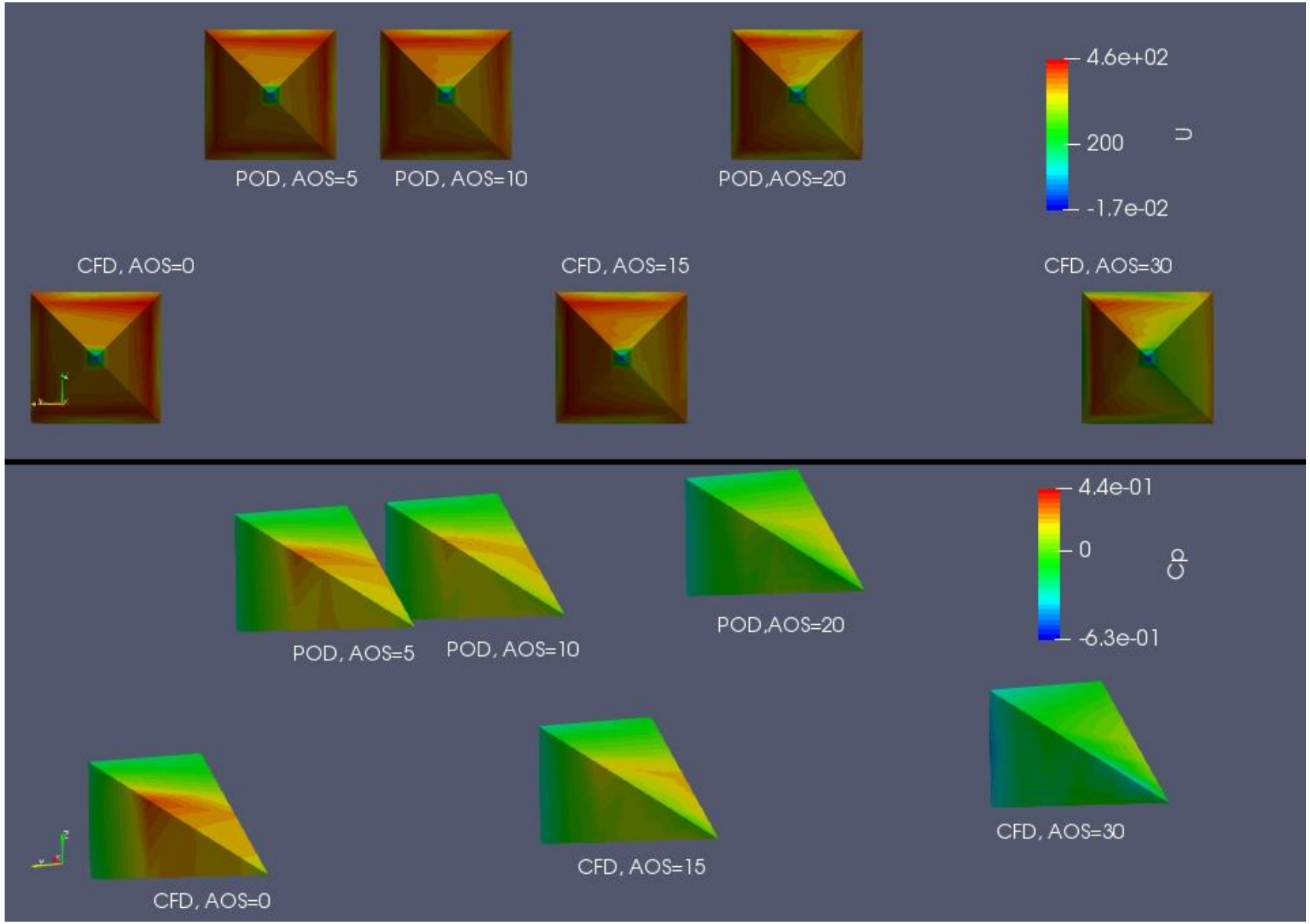
Pareto Solution 결과



ANOVA 결과

향후 추가 계획

POD 모듈



Thanks for your attention.

NEXTfoam CO., LTD.

Convergence Technology Team

Sang Chul, Lee

E-mail: sclee@nextfoam.co.kr

Office: +82-70-8796-3016

NEXTfoam
open source CFD consulting

www.nextfoam.co.kr