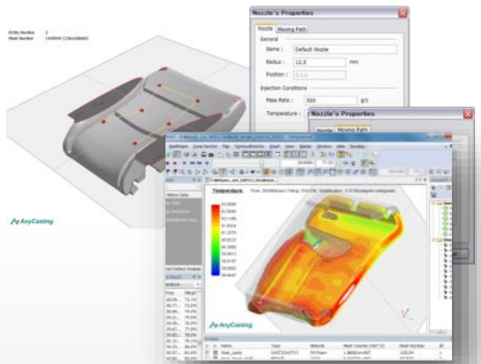
자동차 감성소재 제조공정 시뮬레이션 및 최적화

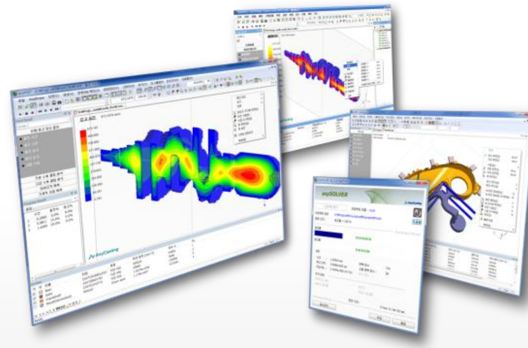
S&WISE Co., Ltd.
이 성 윤

Core Technology and Products

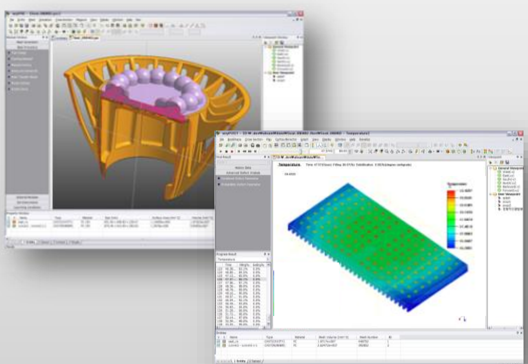
▶ Material Process Engineering Software



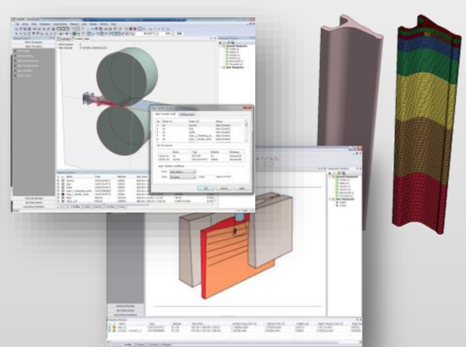
Polyurethane Software



Casting Software



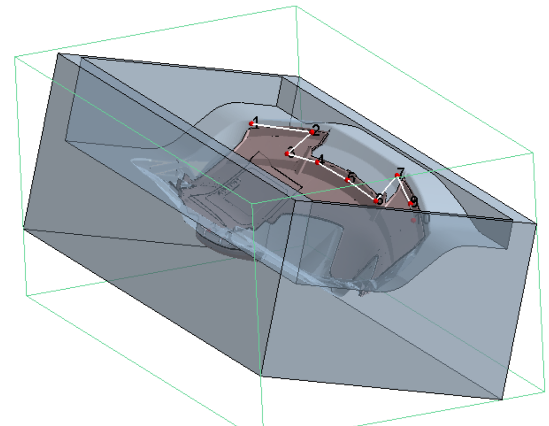
ThermoSYS
OLED, LED, CPV Thermal Analysis



Continuous Casting Software

㈜에스앤위즈

K-Show 2013



Mathematical Formulation (I)

Chemical Reaction Equations

(1) Gelling reaction

$$\text{R-NCO} + \text{R'-OH} \longrightarrow \text{R-NH-}\overset{\overset{\displaystyle O}{\|}}{\text{C}}\text{-O-R'} + \textbf{Heat}$$

Isocyanate *Polyol* *Polyurethane*

(2) Chemical blowing (Water)

$$2\ \text{R-NCO} + H_2O \longrightarrow \text{R-NH-}\overset{\overset{\displaystyle O}{\|}}{\text{C}}\text{-NH-R} + \textbf{Heat} + \mathbf{CO_2}\uparrow$$

Isocyanate *Water* *Urea*

(3) Physical blowing (R11, HCFC, C-Pentane)

$$\text{BL(l)} \longleftrightarrow \text{BG(g)}\uparrow - \textbf{Heat}$$

Thermal Energy Balance

$$\boxed{C_F \frac{dT}{dt} = \left[\frac{(-\Delta H)_{OH}[OH]_O}{\rho_P}\right]\frac{dX_{OH}}{dt} + \left[\frac{(-\Delta H)_W[W]_O}{\rho_P}\right]\frac{dX_W}{dt}} - \lambda\left(-\frac{dL}{dt}\right)$$

(1) **(2)** **(3)**

Heat generation by chemical reaction

Mathematical Formulation (II)

Transport Equations

(4) Momentum Equation

$$\frac{\partial \rho_F}{\partial t} + \nabla(\rho_F \mathbf{v}) = 0$$

$$\frac{\partial}{\partial t}(\rho_F \mathbf{v}) + \nabla(\rho_F \mathbf{v}\mathbf{v}) = -\nabla p + \mu_F \nabla^2 \mathbf{v} + \underline{\frac{1}{3}\nabla(\mu_F \nabla \mathbf{v})} + \rho_F \mathbf{g}$$

Viscous stress from density variation

(5) Energy Equation

$$\rho_F C_F \left(\frac{\partial T}{\partial t} + \mathbf{v} \cdot (\Delta T) \right) = \Delta \cdot (k_F \Delta T) + \rho_F \underline{H_g}$$

Heat generation by chemical reaction

(6) Mass Transfer Equation

$$\frac{\partial}{\partial t}(\rho_F m_{i'}) + \Delta(\rho_F \mathbf{v} m_{i'}) = \underline{R_{i'}}$$

Reaction rate by Arrhenius equation

[OH], [W] = mol per unit volume of polymer mix

BL = mass per unit mass of polymer mix

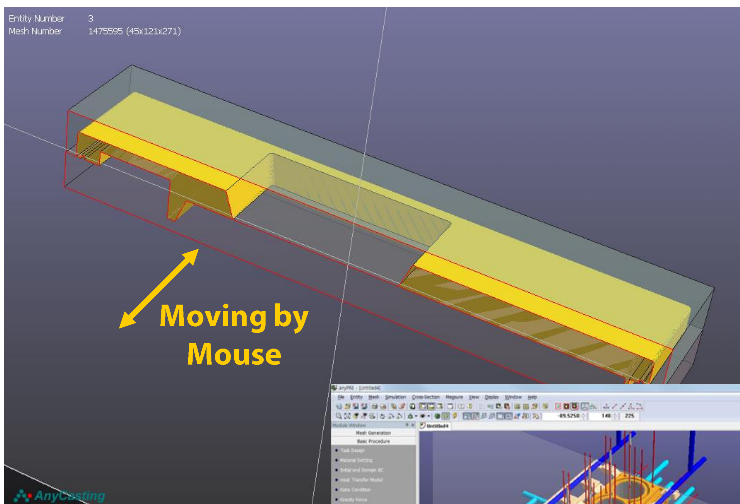
[NCO] = [NCO]$_0$ – 2 ([W]$_0$ –[W]) – ([OH]$_0$ –[OH])

Graphic User-Interface (GUI)

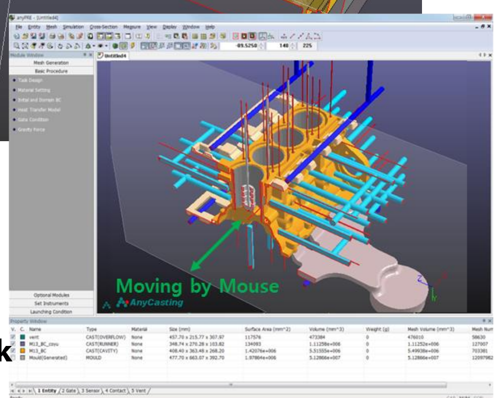
▶ Dynamic Arbitrary Section

1 Product, Die, Duct, etc.

2 Analysis : Filling, Temp., Defects, etc.



Refrigerator Door



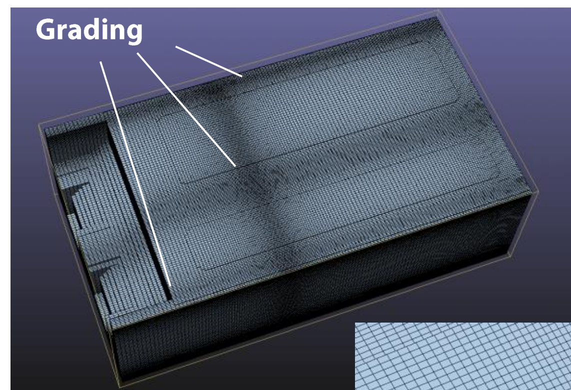
Cylinder Block

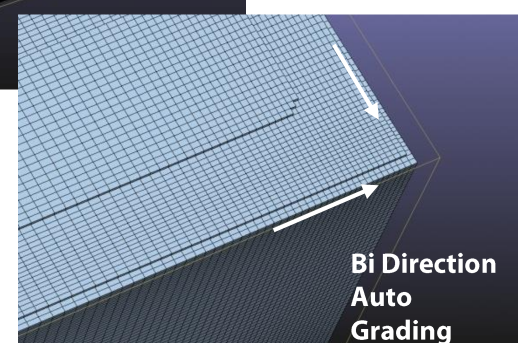
▶ Fast Meshing Algorithm & Variable Mesh Control

Meshing Speed : 6 sec per 20 Mill. Mesh

Automatic Smoothing Algorithm

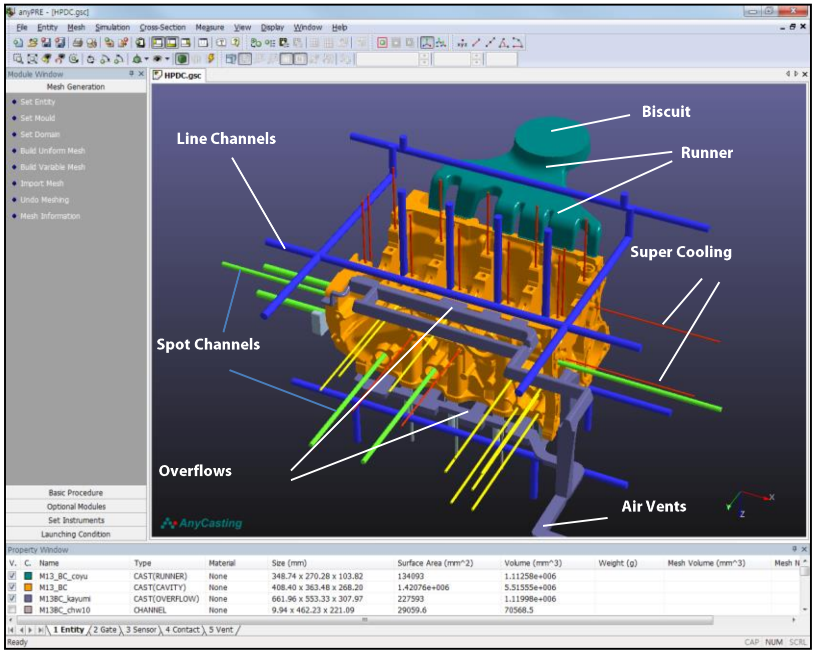
- Specify Mesh Density using Mesh Block
- Higher Accuracy by Mesh Error Checking



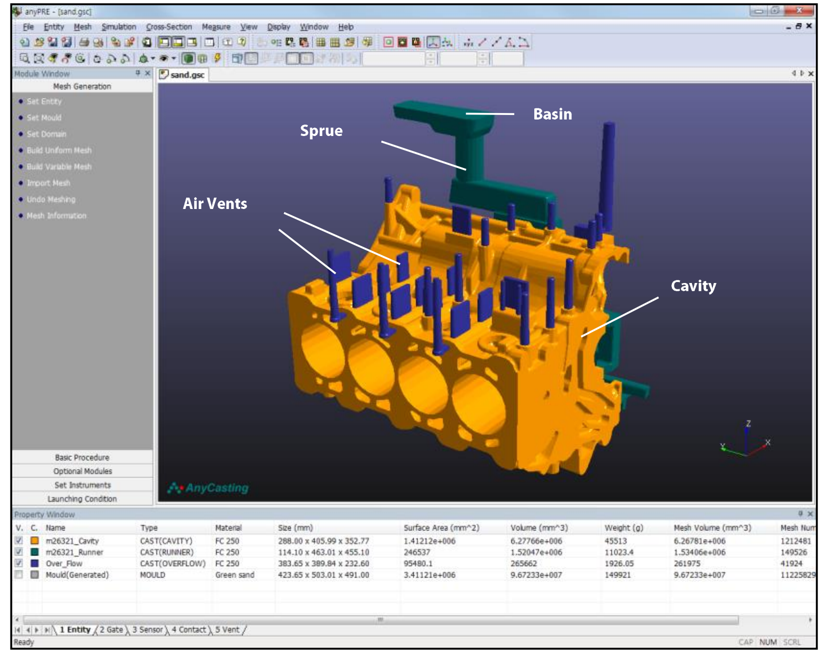


example) Total Analysis of All Casting System

▶ 3-D Mold Filling Porosity, shrinkage/Solidification, Mold



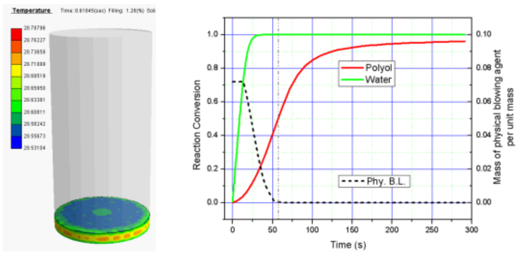
Main Window of Solving system (HPDC)



Main Window of Solving system (SAND)

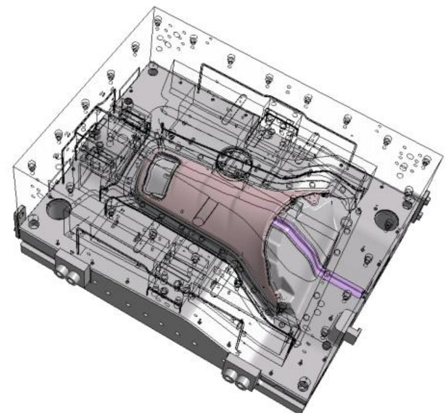
▶ 3-D Thermal Stress / Micro Structure / Mechanical Properties

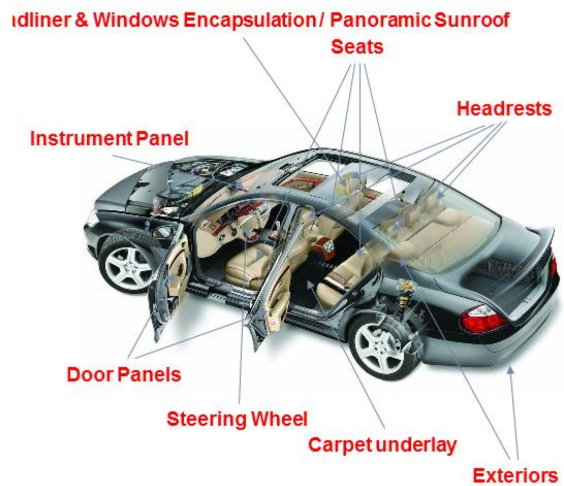
Input



BL Evaporation

Gel Point by Simulation





- Molding material information (some in a database)
- Temperature and material of mold
- Physical Design of the mold
- Polyurethane mixing ratio
- No. of Polyurethane (for multiple density use; seat, bumper etc.)
- Nozzle shape (fixed nozzle, moving nozzle, multiple nozzle)
- Nozzle diameter, moving path
- Speed of PU from nozzle at eac
- Location of vents
- Mold open, close time
- Inserts (headrest, steel plate, fa
- Parting line of mold
- Mold tilting

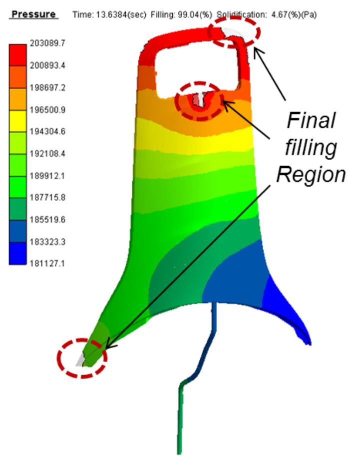
- 고려가능한 공정 변수

- 금형재질 및 조도	- 금형의 온도 (코어 온도)
- 배합비	- 주입구별 이종원액
- 총 주입량	- 주입구별 토출량
- 믹싱노즐 이동경로	- 금형 닫힘시간, 열림시간
- 믹싱노즐 형상	- 에어벤트 위치
- 진공성형	- 스킨,부직포 등의 인서트
- 파팅라인	- 금형 틸팅 (active)

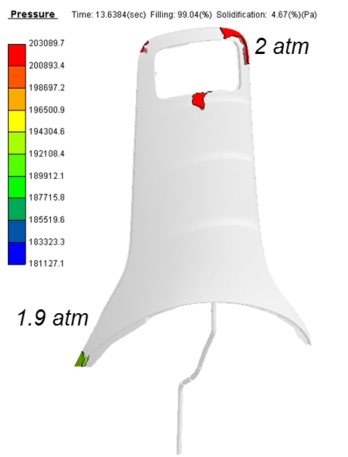
Output

- Predict initial PU location from nozzle
- Predict PU flow pattern, velocity, temper
- Multiple PU tracking
- Predict mis-run of products
- Surface defects (void, crater)
- Density (related to quality)
- Concentration of each species
- Mapping of weld lines
- Predict optimized locations of vents
- Deformation of products (mapping with

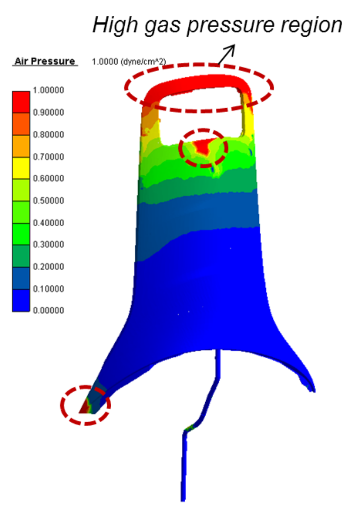
- CAE 해석결과
  - 시간에 따른 발포성형 패턴
  - 속도, 압력, 온도분포
  - 미충전 결함 예측
  - 표면결함, 기포결함 예측
  - 밀도분포 (물성)
  - 웰드라인 추적, 벤트효과 파악
  - ABAQUS, Altair 등과 연계해석



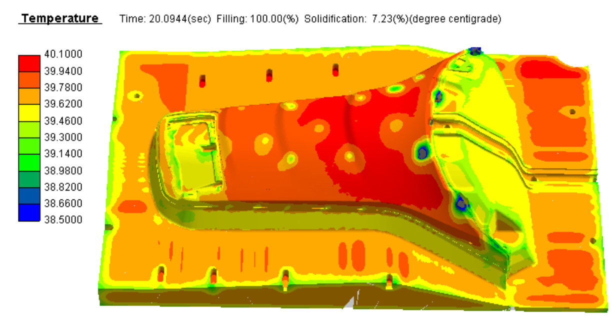
99% filling: Foam Pressure Distribution

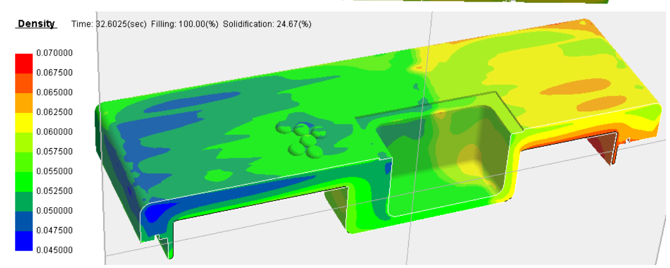


99% filling: Air Pressure Distribution



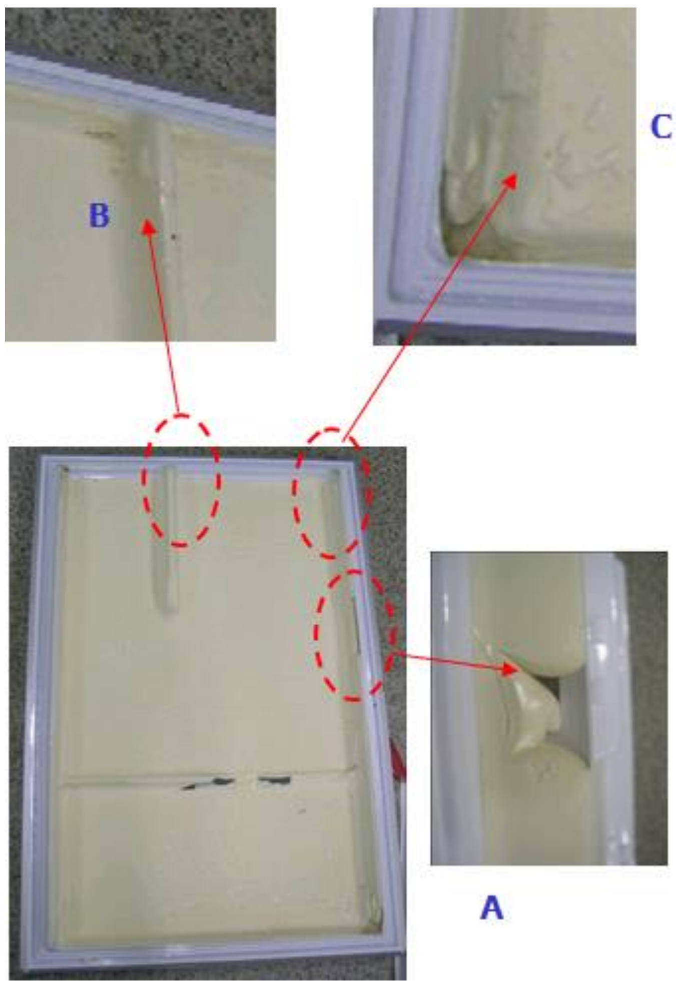
Air Pressure Modulus

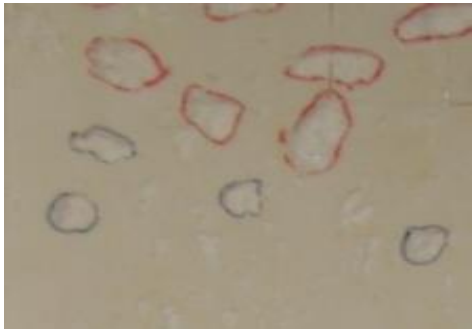




기존 불량품 현황

▶ **미성형(mis-run), 내부결함, 표면결함, 원액불량 발생**





▶ PROBLEM

Defects : Weld line, Air pocket, Mis-run
Surface defects, Deformation etc.

→ Lots of Trial & Error

▶ SOLUTION

Optimized Mixhead Position & Path

Modification Air Vent Design

Optimized Injection Condition

Application New Material

Overall Simulation Process

▶ Flow Chart

Step 1. **Checking Data** — Correct information or not

Step 2. **Making DB (PU solution)** — Using DAPS profile

Step 3. **CAD Modeling & Transfer** — Transfer format to STL

Step 4. **Setting Conditions** — Using Pre-processor

Step 5. **Solving** — Using AnyFOAM Solver

Step 6. **Observe Result** — Using AnyFOAM Post

Preparation of Data

1. Material Information
2. Foaming Condition
3. Modeling

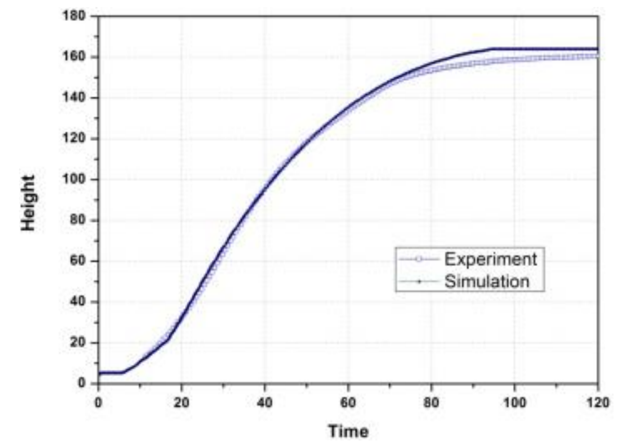
Process of Simulation (1)

▶ Step 1. Checking Data

Checking Data

1. DAPS profile
   → mold size check
   → temperature / rising profile
2. Foaming liquid mixing ratio
3. Condition / Modeling

Height profile

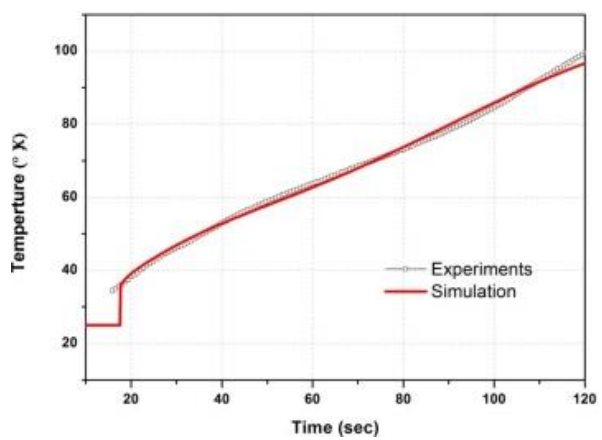


▶ Step 2. Making DB

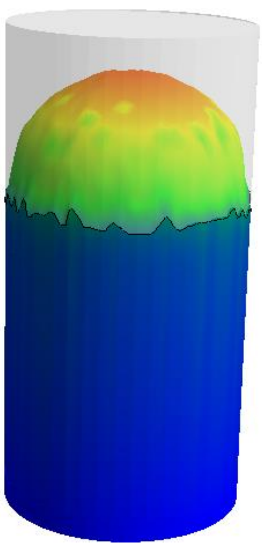
Making DB (PU solution)

using **anyDB**

1. Making mold model
2. Simulate DAPS test using S/W
3. Compare experiment and simulation result (rising / Temp.)



Temp. profile

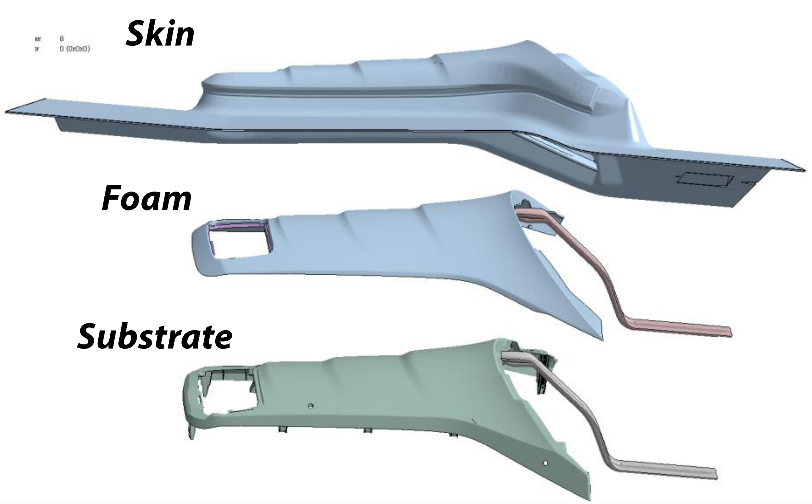


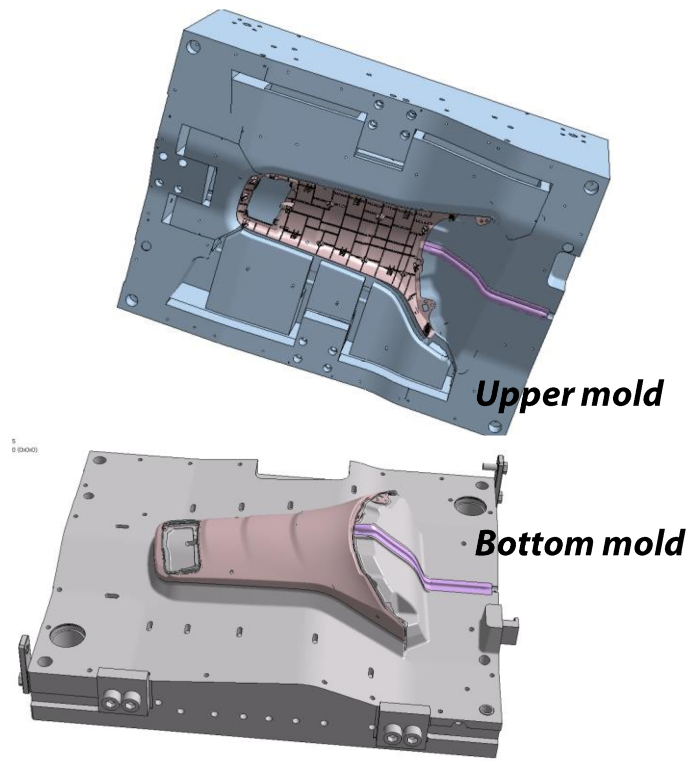
Process of Simulation (2)

▶ Step 3. Transfer format and Modify Modeling

Transfer format and Modify Modeling

1. Original modeling file check
2. Make necessary part → mold (for parting line)
   Modify modeling → broken part
3. Change file format (to STL)



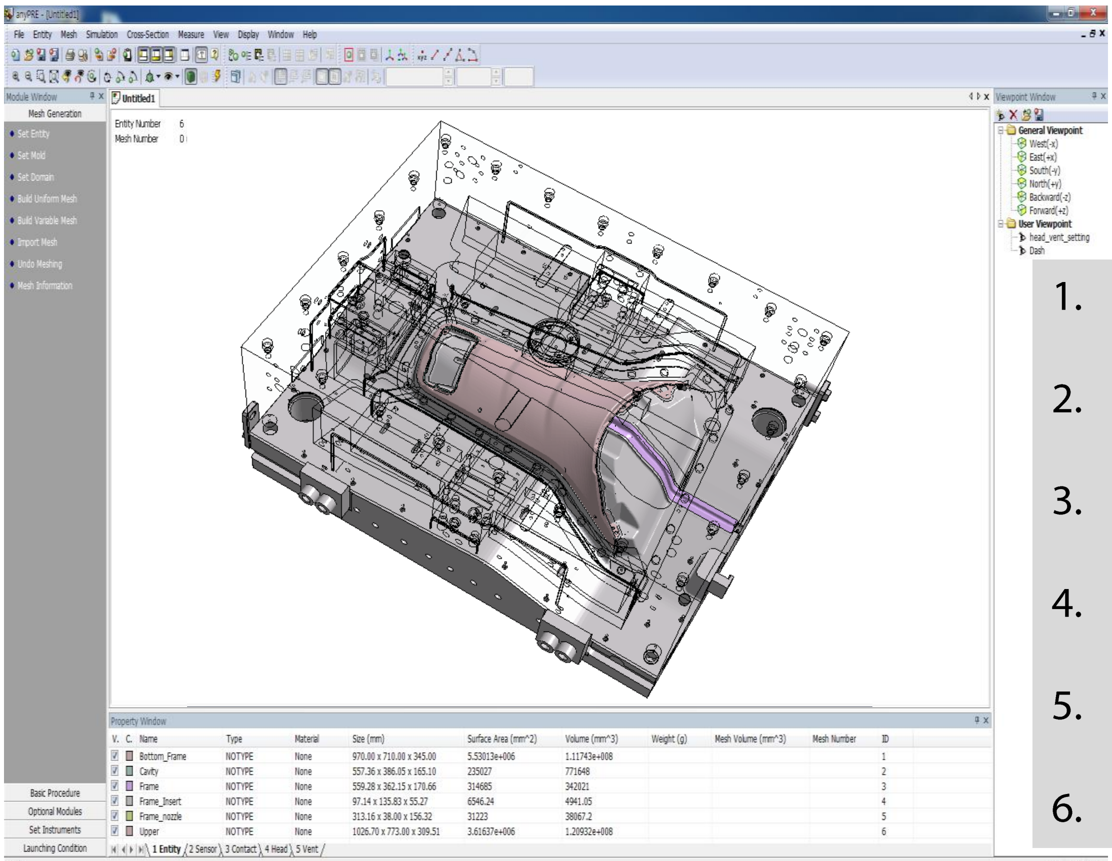


Process of Simulation (3)

▶ Step 4. Setting Condition

Setting Conditions

Set condition using **Pre-processor**



1. Set Entity
2. Mesh Generate
3. Set Material
4. Set HTC (Heat Transfer Coefficient)
5. Set Variable Option
6. Set Pour Pattern & Condition

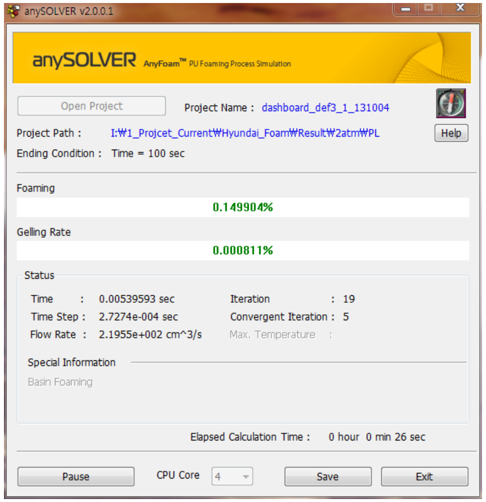
Process of Simulation

▶ Step 5. Solving

Solving

Using **Solver**

1. Possible to intermediate save
2. Possible to continues solve using saved file
3. User can observe the result during solving
4. Batch runner

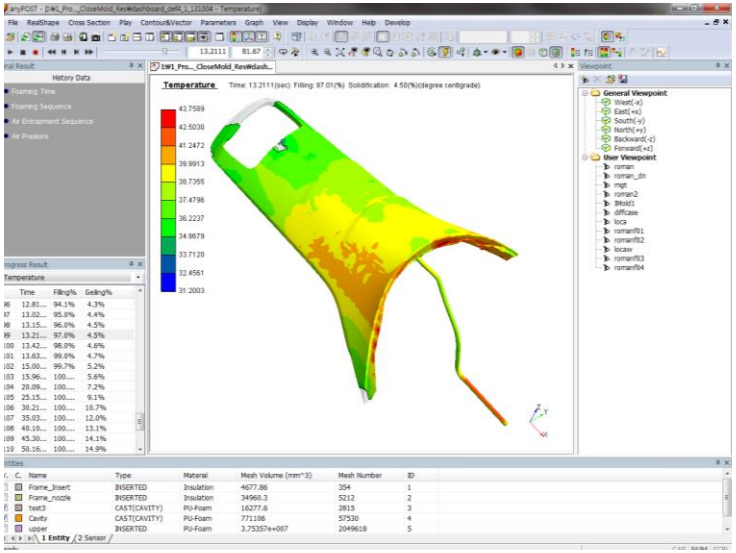


▶ Step 6. Observe Result

Observe Result

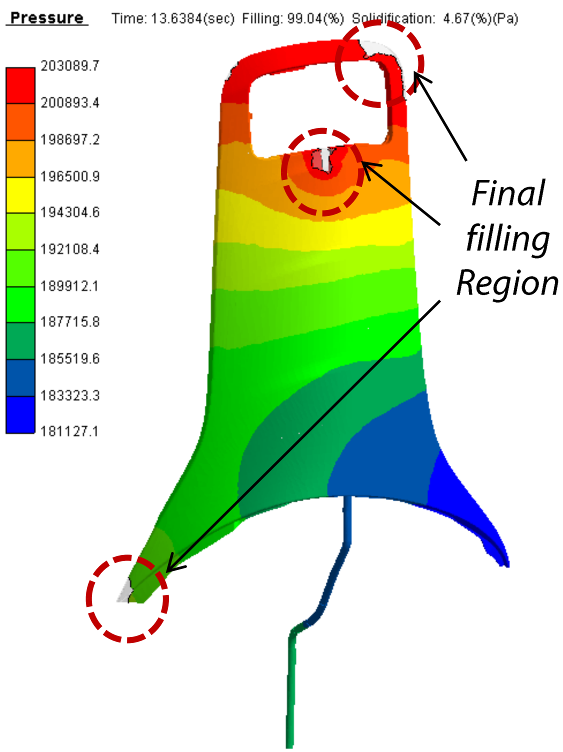
Using **Post-processor**

1. Foaming Sequence
2. Air Entrapped area (Air Pressure)
3. Temperature
4. Density
5. Pressure

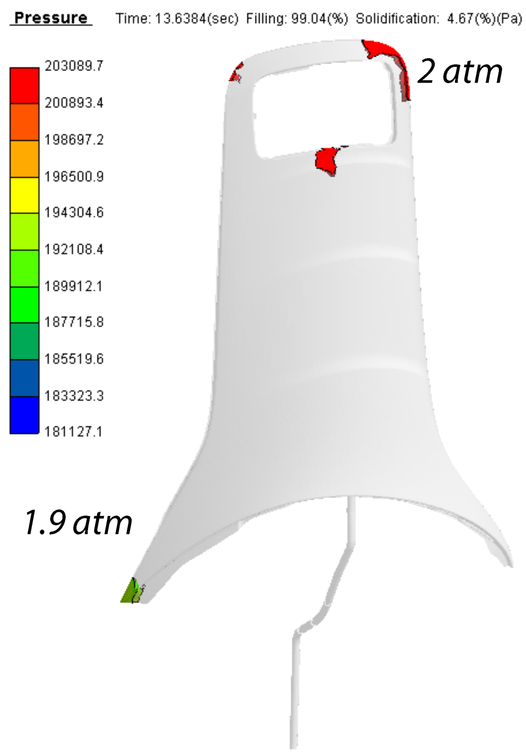


Overall Foaming Pattern

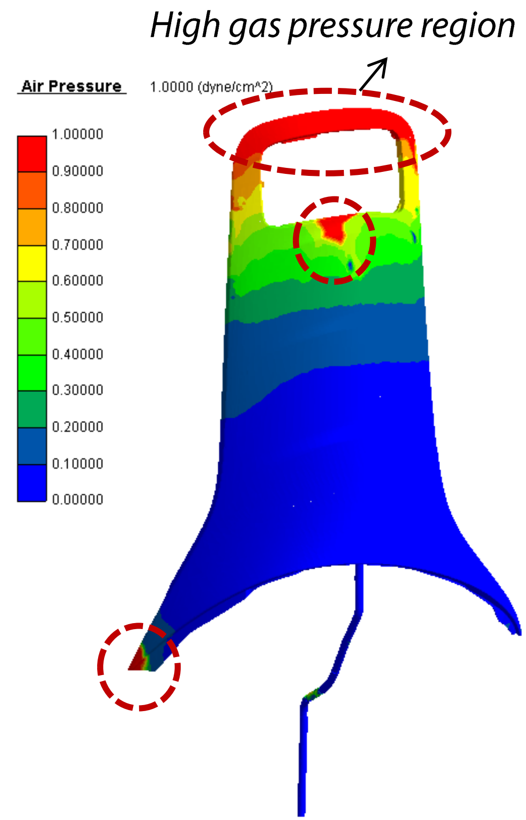
▶ Air Entrapment (air pressure)



99% filling: Foam Pressure Distribution



99% filling: Air Pressure Distribution



Air Pressure Modulus

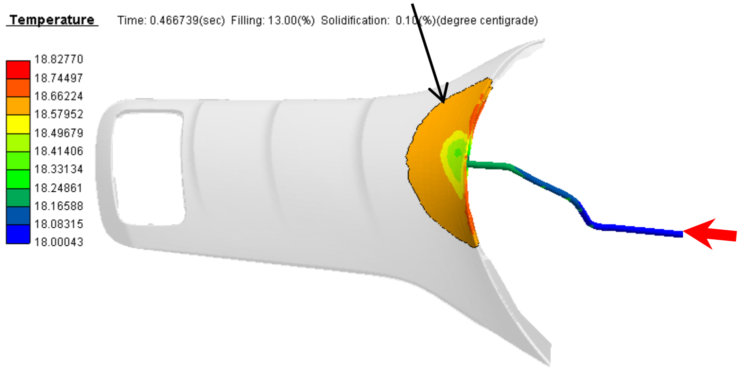
Air pressure Modulus: it show the relative pressure of air at the final foaming state

→ This function is very simple and more comfortable to check the defect area than air entrapment sequence

Overall Foaming Pattern

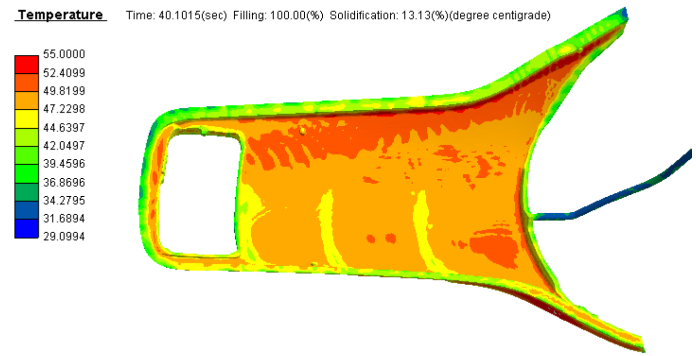
▶ Temperature Distribution

Temperature rise during pouring

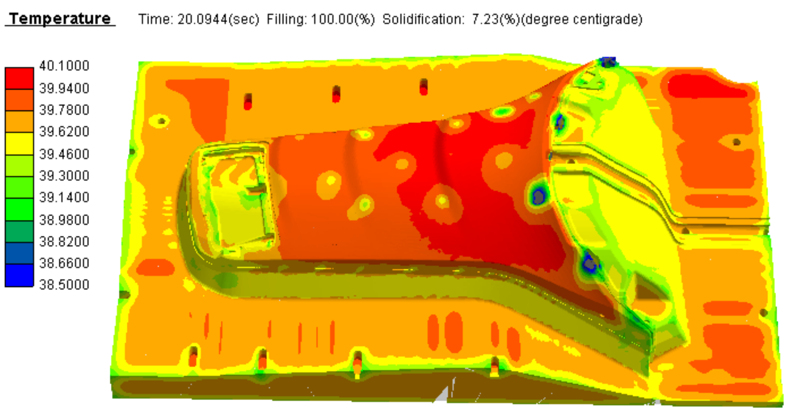


Foam Front: 0.5 sec

Temperature Rise in Exothermic Reaction

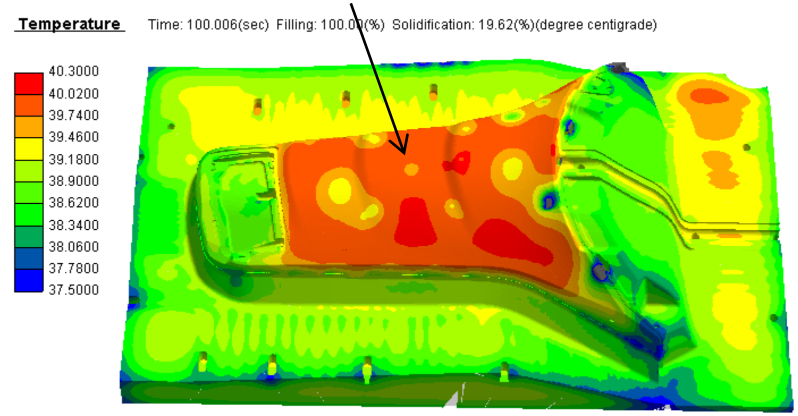


Foam Back: 40 sec



Upper Mold: 20 sec

Temp. Rise adjacent to the foam



Upper Mold: 100 sec

PU Automotive Solutions

Automotive applications

BASF
The Chemical Company

- ***Easy Processing***
  - *- Reaction-Injection foaming*
  - *- Process-energy saving*

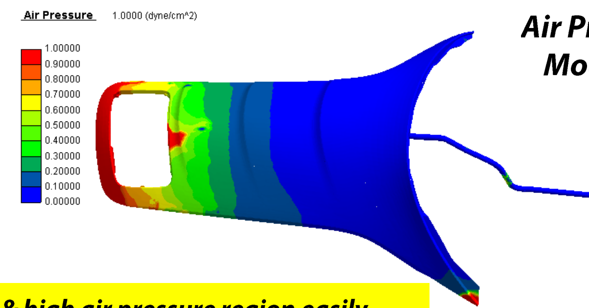
- ***Tailor-made System***
  - *- Systemized PU raw materials*
  - *- Adjustable physical properties*

- ***Light Weight & Low Density***
  - *- Adjustable foam density*
  - *- Cost-effectiveness*

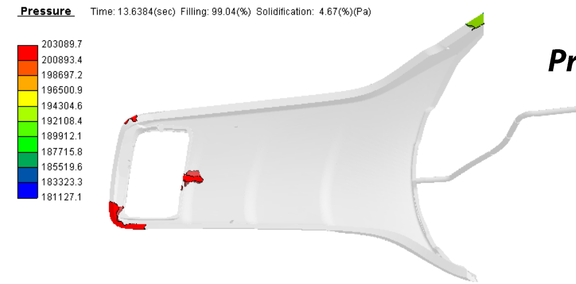
- ***Suitable for Auto Interior/Exterior***

Prediction and Optimization

Air Pressure



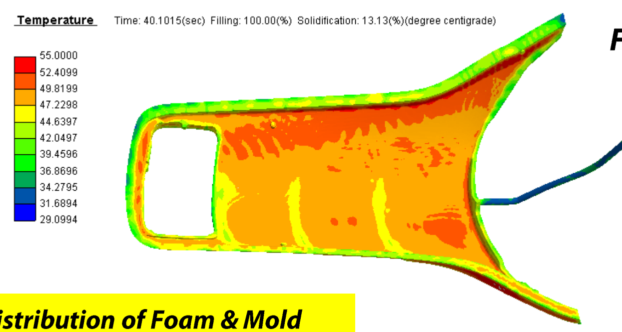
Air Pressure Modulus



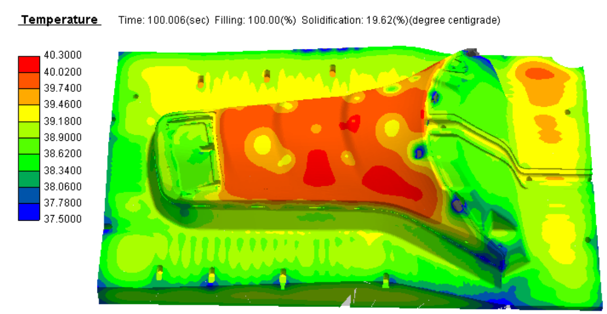
Air Pressure

Can check void area & high air pressure region easily

Temp. Distribution



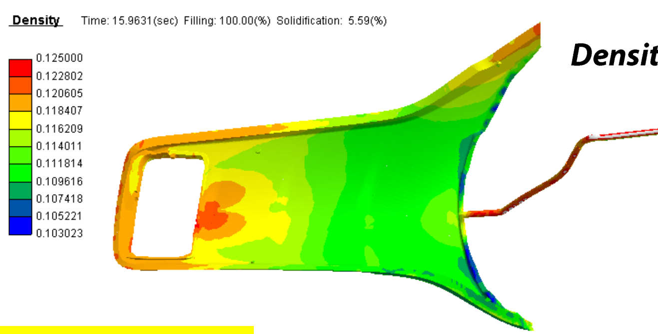
Foam



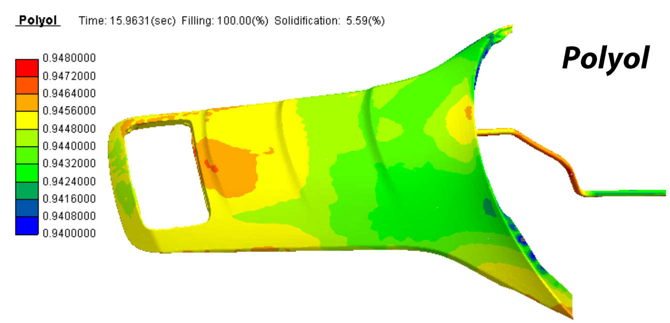
Mold

Can check Temp. distribution of Foam & Mold

Density & Polyol Distribution



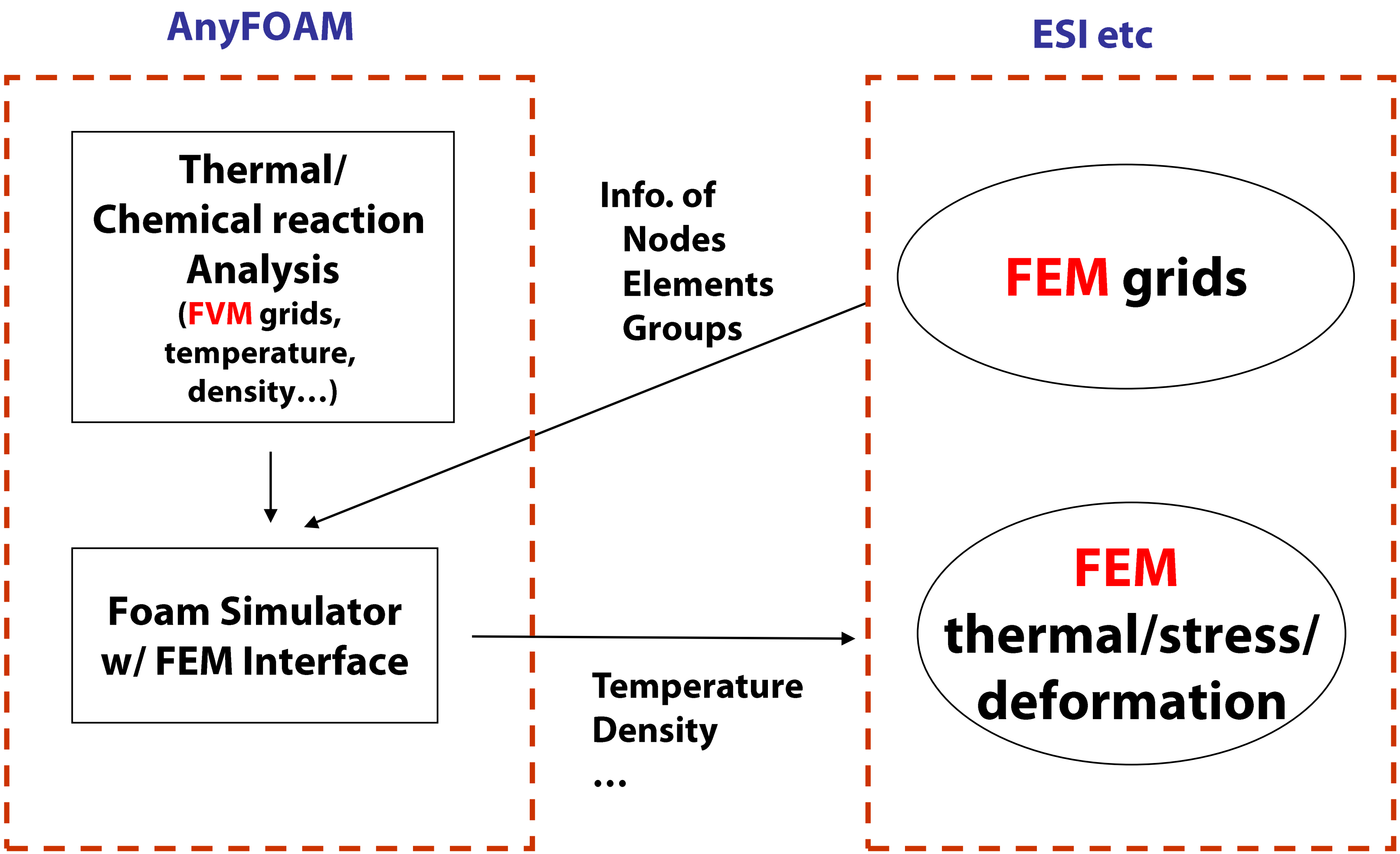
Density



Polyol

Can check foam properties distribution

FEM Interface with ESI, ABAQUS, ANSYS, Altair etc



Summary

1. 기업 요구에 의한 개발/검증된 소프트웨어 개발
   * 가전업체 → 자동차부품업체, 소재업체, 수송기분야
   복합재 부품업체, 3-D 프린팅업체

2. 개발사: 기술력 습득
   (1) 화학분야의 반응에 관한 해석 기법
      → 극저온 충격강도 소재 개발: NASA
      → 에어로젤 등 초고효율 단열재 개발
   (2) 고체/액체/기체를 모두 다루는 해석 기법
   (3) 고도의 free surface tracking 해석 기법

3. Improve Quality, Cost,
   especially Delivery(development speed)

- 수송기기 – 스티어링휠, 에어백/혼 커버, 기어노브, 암레스트 등
- 가구제품 – 암레스트, 시트패드 (유아시트), 침대 등
- 신발제품 – 반응성 고무재질, 깔창
- 의료기기 – 휠체어 타이어, 패드
- 우주항공 – 무결함 패드, 복합단열재