Catalyst pellet modelling by FEMLEB

Model Selection

🌃 Model Navigator New Model Library User Models Settings -Multiphysics 2D ¥ Space dimension: Remove Add EMLAB 🔁 ۸ 🖃 😋 Chemical Engineering Module Geom1 (2D) 표 💼 Energy balance Incompressible Nevier-Stokes (ns) 🖃 🖂 Mass balance i Convection and Diffusion (cd) Convection and Diffusion Fransient analysis Electrokinetic Flow Maxwell-Stefan Diffusion and Convection < Nernst-Planck + Dependent variables: c 표 💼 Momentum balance Application Mode Properties... + 📄 Pseudo 3D < > Add Geometry... Ruling application mode: Dependent variables: c2 Incompressible Navier-Stokes (ns) ¥ Application mode name: cd2 ¥ Element: Lagrange - Quadratic Multiphysics OK Cancel

- 1. FEMLEB 실행
- 2. Multiphysics 클릭
- 3. Fluid Dynamics에서

Incompressible Navier-Stokes 선택 후 Add

4. Chemical Engineering Module 에서 Mass balance >

Transient analysis 선택 후 Add



Axis Grid	
🔽 Axis equal	
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	OK Cancel Apply
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Axis Grid	
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Axis Grid Auto Visible Labels x-y grid x spacing: 0.001 Extra x: 0.0009 y spacing: 0.001 Extra y: 0.0021, 0.0039	z grid z spacing: 0.2 Extra z:

- Option Menu Axis/Grid setting
- 2. 주어진 Axis/Grid 값 대입
- 3. OK클릭

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Height:	0.006	
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y:	0	

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- 1. Draw Menu Specific object Rectangle 선택
- 2. 너비와 높이 지정 후 OK
- Status Bar 의 Solid 더블 클릭 해서 선택 해제
- 4. Draw Menu Draw Objects 2nd degree Bezier curve 로 반원 그림



Name	Expression	Value	
RO	0.66	0.66	1
mu	2.6e-5	2.6e-5	
v0	0.1	0.1	
D	1e-5	1e-5	
Deff	1e-6	1e-6	
k	100	100	
clO	1.3	1.3	
			-
		OK Cancel App	ly



- 1. Options Menu Constants
- 지정된 상수 값 Name 과 Expression 입력
- 3. Multiphysics Menu NS 선택

NS Eqn Boundary setting

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- 1. Physics Menu Boundary Settings 선택
- 2. 각 Boundary 값지정

CD Eqn Boundary setting

	Boundary Settings - Convection and Dimusion (cd)
	Equation
	c=c ₀
(cd) : [Untitled]	
stprocessing Multiphysics Help	Boundary selection Boundary conditions 1 Soundary conditions
🖴 🕼 🗩 🛛 Model Navigator	Quantity Value/Expression Description
1 Incompressible Navier-Stokes (ns)	4 Concentration
◆2 Convection and Diffusion (cd)	
	Select by group
	Interior boundaries
	OK Cancel Apply
Boundary Settings - Convection and Diffusion (cd)	Boundary Settings - Convection and Diffusion (cd)
Equation	Equation
n•N = 0; N = -D⊽c+cu	n N = 0; N = -D⊽c
Boundary selection Boundary conditions	Boundary selection Boundary conditions
Boundary condition: Insulation/Symmetry	Boundary condition: Convective flux
3 Quantity Value/Expression Description	3 Quantity Value/Expression Description
4 Constant watch	4 No No Inward flux
Select by group	Select by group
Interior boundaries	Interior boundaries
OK Cancel Apply	OK Cancel Apply

- 1. Multiphysics Menu- CD 선택
- 2. Physics Menu Boundary Settings 선택 후, 각 Boundary 값 지정

NS Subdomain setting

1	Subdomain Settings - Incompressible Navier-Stokes (ns) 🛛 🔀	
	Equations	
	$\rho(\mathbf{u} \cdot \nabla)\mathbf{u} = \nabla \left[-p\mathbf{I} + \eta(\nabla \mathbf{u} + (\nabla \mathbf{u})^T) \right] + \mathbf{F}$	
	- ⊽ • u = 0	
	Subdomain selection Physics Init Element	
	Fluid properties and sources/sinks	
	2 Library material: Load	
	Quantity Value/Expression Description	$\langle \cdot \rangle$
	p R0 Density	
	n mu Dynamic viscosity	
	F D Volume force, y-dir.	
	Select by group	::
	Active in this domain	
	OK Cancel Apply	
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	Subdomain Settings - Incompressible Navier-Stokes (ns)	a.
6	Subdomain Settings - Incompressible Navier-Stokes (ns) Equations ρ(u·⊽)u = ⊽ {- βl + η(⊽u + (⊽u) ^T)] + F	3
6	Subdomain Settings - Incompressible Navier-Stokes (ns) Equations Equations $\rho(\mathbf{u} \cdot \nabla) \mathbf{u} = \nabla \{-p\} + \eta (\nabla \mathbf{u} + (\nabla \mathbf{u})^T)\} + F$ $-\nabla \cdot \mathbf{u} = 0$	3
6	Subdomain Settings - Incompressible Navier-Stokes (ns) Σ Equations ρ(u·▽)u = ▽ {- pl + η(▽u + (▽u) ^T)] + F - ▽·u = 0 Subdomain selection Physics linit Element	3
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- 6 5	Subdomain Settings - Incompressible Navier-Stokes (ns) Equations $p(\mathbf{u} \cdot \nabla) \mathbf{u} = \nabla [-p] + \eta (\nabla \mathbf{u} + (\nabla \mathbf{u})^T)] + F$ $- \nabla \mathbf{u} = 0$ Subdomain selection Physics Physics Image: Fluid properties and sources/sinks Library material: Load	
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6 5 49	Subdomain Settings - Incompressible Navier-Stokes (ns) Equations $p(\mathbf{u} \cdot \nabla) \mathbf{u} = \nabla \{-\mathbf{p}\} + \eta(\nabla \mathbf{u} + (\nabla \mathbf{u})^T)\} + \mathbf{F}$ $- \nabla \cdot \mathbf{u} = 0$ Physics init Element Subdomain selection Physics init Element Image: Subdomain selection Physics init Element Image: Subdomain selection Physics init Element Image: Subdomain selection Image: Subdomain selection Image: Subdomain selection Physics init Element Image: Subdomain selection Image: Subdomain selection Image: Subdomain selection Image: Subdomain selection	
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5 49 3	Subdomain Settings - Incompressible Navier-Stokes (ns) Equations $p(\mathbf{u} \cdot \nabla) \mathbf{u} = \nabla \{-p\} + \eta (\nabla \mathbf{u} + (\nabla \mathbf{u})^T\} \} + F$ $-\nabla \cdot \mathbf{u} = 0$ Physics Init Element Subdomain selection Fluid properties and sources/sinks Image: Select by group Physics Init Element Select by group Physics Init Element Fx Ovanticy Value/Expression Description p Dynamic viscosity Fx Volume force, x-dir. Fy Volume force, y-dir. Artificial Diffusion Artificial Diffusion	
- 6 5 49 3	Subdomain Settings - Incompressible Navier-Stokes (ns) Equations $p(u \cdot \nabla)u = \nabla [-p] + \eta (\nabla u + (\nabla u)^T)] + F$ $-\nabla u = 0$ Subdomain selection Image: Select by group Active in this domain Physics init Element Physics init Element Image: Select by group Active in this domain	
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- 1. Multiphysics Menu NS 선택
- 2. Physics Menu Selection Mode Subdomain Settings 선택
- 3. 각 Subdomain에 수치 대입

CD Subdomain Settings

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- 1. Multiphysics Menu CD 선택
- 2. Physics Menu Selection Mode Subdomain Settings 선택
- 각 Subdomain Settings 에 수치 대
 입



- 1. Mesh Menu Mesh Parameter 선택
- 2. Boundary 최대값 지정



Solver Manager	
Geom1 (2D) Geom1 (2D) Convection and Diffusion (cd)	1. Solve Menu – Solver Manager 선택 2. Solve For 탭에서 CD 선택해제

Auto select solver Solver: Stationary linear Stationary nonlinear Preconditioner: Time dependent Settings Eigenvalue Settings Parametric linear Solution form: Ceneral Symmetric matrices	Analysis:	General Nonlinear Adaption Advanced
Stationary nonlinear Time dependent Eigenvalue Parametric linear Parametric nonlinear Solution form: General Symmetric matrices	✓ Auto select solver Solver:	Linear system solver Linear system solver: Direct (UMFPACK) Preconditioner:
Parametric linear Parametric nonlinear Solution form: General Solution form: Adaption	Stationary nonlinear Time dependent Eigenvalue	Settings
Adaption	Parametric linear Parametric nonlinear	Solution form: General
	Adaption	<u> </u>

Solve

- 1. Solve Menu Solver Parameter 선택
- 2. General탭에서 Staionary nonlinear 선택

Progress - Solve Problem					
Matrix factorization					
Progress Log					
Description	Progress	Convergence	Parameter	Value	
Nonlinear solver	92 %	5.19e-7	Step	3	Stop
UMFPACK	0%		Step	0	Stop
					Stop
Close automatically					Cancel

1. Solve Menu – Solve Problem 클릭

Solve

2. 주어진 조건에서의 값이 계산 됨

Result



<Surface : Velocity Field>

Result



<Streamline : Velocity Field>

Result





흐르는 유체 속의 다공성 촉매에 의해서 유체에 속도구배가 생기게 된다. Pellet이 있는 부분은 속도가 느려지고 표면 부분은 상대적으로 속도 가 빨라지는데 이것은 Surface plot에서 파란 색으로 부터 붉은색으로 나타난다. 다음으로 이것을 Streamline으로도 나타낼 수 있다.

Surface plot

Streamline