

Maxwell 3D Magnetostatic (Solenoid)

Overview

- 해석 모델: 솔레노이드 (Solenoid) - Core, Plunger, Coil로 이루어 짐
- 해석 목적

- 전기강판 재질 생성 (BH Curve 입력) - Maxwell 결과와 수계산 결과의 차이점 확인

- 해석 솔버 : Maxwell 3D Magnetostatic(정자계 해석)
- 해석 결과
 - Force Value of Plunger
 - calculate Flux density in airgap
 - calculate Magnetic Flux in airgap







ANSYS Electronics Desktop 실행



- 1. Save as... \rightarrow Solenoid
- 2. 상단 메뉴 Project → Insert Maxwell 3D Design 클릭
- 3. Name 변경 → "Solenoid"
- 4. 상단 메뉴 Maxwell 3D → Solution Type 클릭
- 5. Magnetostatic 선택 후 "OK"

Solution Type: 4_solenoid - Solenoid					
Magnetic:					
C Eddy Current					
C Transient					
Electric:					
C Electrostatic					
C DC Conduction					
🗖 Include Insulator Field					
C Electric Transient					
OK Cancel					





1. 상단 메뉴 Modeler → Import 클릭



2. Solenoid.sm3 선택후 열기

🔥 Import File					×
찾는 위치(!):	000000000_20	160322_education	•	← 🗈 💣 📰 ◄	
Ca	이름	*		수정한 날짜	유형
최근 위치	20160323 EX.	aedtresults		2016-03-17 오전 9:	파잌 폭더
	solenoid.sm3			2016-03-17 오전 9:	SM3 파일
바탕 화면					
라이브러리					
1					
컴퓨터					
네트워크	•	III			
	파일 이름(<u>N</u>):	solenoid, sm3		•	열기(<u>0</u>)
	파일 형식(<u>T</u>):	All Modeler Files (*,gds	:)*, sm3)*, s	sat;∗,stp; ∗,st 💌	취소
PersonalLib	serLib SysLib				
Validation and Healin	g Options				
Quick					
C Strict	Auto C Mar C	nual			

- 1. 도면에서 Ctrl + A 전체 선택
- 2. 마우스 우클릭
 - > Edit
 - > Sweep
 - > Around Axis
- 3. Sweep Around Axis Sweep axis : Z축 Angle of sweep : 360 Draft angle : 0 Draft type : Round Number of segments : 120 "OK"





■ History tree "band", "coil", "core", "plunger"를 클릭하고 아래 그림과 같이 Properties 설정을 변경

<	History	tree	>



Properties			Ψ×
Name	Value	Unit	Evalua
Name	band		
Material	"vacuum"		"vacuu
Solve Inside	v		
Orientation	Global		
Model	v		
Display Wireframe	~		
Color			
Transparent	0,8		

Properties			Ψ×
Name	Value	Unit	Evalua
Name	coil		
Material	"copper"		"сорре
Solve Inside	v		
Orientation	Global		
Model	~		
Display Wireframe			
Color			
Transparent	0,8		

Properties 🛛 🕹 🗸				
Name	Value	Unit	Evalua	
Name	core			
Material	Edit		"Steel"	
Solve Inside	V			
Orientation	Global			
Model	V			
Display Wireframe				
Color				
Transparent	0,8			

Properties			Ψ×
Name	Value	Unit	Eva
Name	plunger		
Material	Edit		"Ster
Solve Inside	v		
Orientation	Global		
Model	v		
Display Wireframe			
Color			
Transparent	0		

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"core"와 "plunger"의 재질은 Edit를 눌러서 아래 창을 띄웁니다.

Select Definition			_		X
Materials Material Filters					
Search Parameters Search by <u>N</u> ame Search Search	Criteria Name ive Permittivity	C by Pro	Libraries perty ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓	Show Project definitions als t	✓ Show all libraries
Name	Location	Origin	Relative Permeability	Bulk Conductivity	Ma A Coe
aluminum_EC	SysLibrary	Materials	1,000021	36000000siemens/m	0
aluminum_no2_EC	SysLibrary	Materials	1,000021	33000000siemens/m	0
Arlon 25FR (tm)	SysLibrary	Materials	1	0	0
Arlon 25N (tm)	SysLibrary	Materials	1	0	0
Arlon AD1000 (tm)	SysLibrary	Materials	1	0	0
Arlon AD250A (tm)	SysLibrary	Materials	1	0	0
Arlon AD255A (tm)	SysLibrary	Materials	1	0	0
Arlon AD255C (tm)	SysLibrary	Materials	1	0	0
Arlon AD260A (tm)	SysLibrary	Materials	1	0	0
Arlon AD270 (tm)	SysLibrary	Materials	1	0	0
					v
View/Edit Materials	erial	<u>C</u> lone Mat	erial(s) <u>B</u> e	emove Material(s)	► Export to Library
				확인	취소 도움말

1. Add Material... 클릭 (새로운 재질 생성)



SNE

- O -X

 \Leftrightarrow

1.00E+005

Export Dataset...

В

tesla

- 1. 상단메뉴 Draw > Region 클릭
- 2. Region Pad all direction simlarly 체크 Value : 50 "OK"
- 3. History tree > coil 우클릭 > Edit > Surface > Section 클릭
- 4. YZ 평면으로 "OK"

Region			X				
Padding Data: 📀 Pad all directions similarly							
O Pad individual directions							
	C Transverse padding						
Direction	Padding type	Value	Units				
All	Percentage Offset	50					
Save as default							
	ОК С	ancel					
		_					





- 1. Coil_section1 우클릭 > Edit > Boolean > Separate Bodies
- 2. Coil_Section1_Separate1 > Delete!
- 3. Coil_section1 우클릭 > Assign Excitation > Current.. 클릭
- 4. Current Excitation
 - > Value : 50A
 - > Type : Solid
 - > "OK"



Current Excitation				x
Name:	Current1			
Parameters				
Value:	50	A	-	
2				
Туре:	• Solid •) Stranded		
	Swa	ap Direction		
		e Defaulte		
		e D'erduks		
	ОК		Cancel	



- 1. History tree에서 plunger 우클릭 > Assign Parameters > Force 클릭
- 2. 다른 설정 필요 없이 "확인"
- 3. Core와 Plunger Ctrl로 같이 우클릭 > Assign Mesh Operation > Inside Selection > Length Based
- 4. > Maximum Length of Elements : 0.5mm > "OK"

Force Setup	Element Length Based Refinement	×
Force Post Processing	Name: Length1	🔽 Enable
Name: Force1	Restrict the length of elements	mm
C Lorentz	Restrict the number of additional elements	000
<u>확인</u> 취소	OK Cance	el

- 1. Coil 우클릭 > Assign Mesh Operation > Inside Selection > Length Based 클릭
- 2. Maximum Length of Elecments : 2mm "OK"
- 3. 상단메뉴 Maxwell 3D > Analysis Setup > Add Solution Setup 클릭
- 4. Solve Setup > 다른 설정 없이 "확인"

Element Length Based Refinement	×	Solve Setup ×
Name: Length2 IV Enable		General Convergence Expression Cache Solver Defaults Name: Setup1 Irred Enabled
Restrict the length of elements Set maximum element length:		Adaptive Setup Maximum Number of Passes: 10
Restrict the number of additional elements		Percent Error: 1 Parameters
OK Cancel		Solve Fields Only Solve Matrix: After last pass Only after converging



- Project Manager > Solenoid 우클릭
 > Validation Check... (현재 모델 이상유무 확인)
- 2. Error 없으면 "Close"
- **3. Analysis > Setup1 우클릭 > Apply Mesh Operations** (Mesh 분포 확인)



Validation Check: 20160323 EX - 05 Solenoid

X

	Solids		AT+	Create Mesh Plot		×	
Ē		-		Name:	Mesh1		
	🕂 🖅 plunge		Expand All	Design Name:	Maxwell3DDesign1		
	🗄 🖉 band		Collapse All	Context			
	i		Edit •	Solution:	Setup1 : LastAdaptive	•	
÷.	coil_Section		Create 3D Component			-	
	Global	5	Assign Material	Field Type:	Fields		
	Planes Global:XY Global:XZ Global:YZ Lists		View Properties Assign Band Assign Boundary Assign Excitation		Done 2	ncel	
			Assign Parameters				
			Assign Mesh Operation				
			Fields •				
			Plot Mesh	1			

- 1. History tree > Plunger 우클릭 > Plot Mesh 클릭
- 2. "Done" (View 기능을 통해서 다른 모델들은 숨기고 보면 편리함.)

- 1. 상단 메뉴 Maxwell 3D > Results > Solution data 클릭
- 2. Mesh Statistics 탭 > Total number of elements : 63,351개

S S	olutions	: solenoid - I	Maxwell3DDesig	n1				-	- 🗆	×
Simula	ation:	Setup1		•						
Desigr	n Variatio	on:						1 🖌		
		,	- 1- 1	La cara a March d]] -		
Profi	ile Co	nvergence	Force Torque	Matrix Mesn	statistics					
_	Total n	umber of eleme	ents: 63351							_
		Num Tets	Min edge length	Max edge length	RMS edge length	Min tet vol	Max tet vol	Mean tet vol	Std Devn (vo	ol)
ba	ind	7228	0.0805207	1.6933	0.657251	1.38131e-08	0.00470175	0.00017469	0.000265625.	
со	il	2552	0.345993	1.86695	1.44388	3.51451e-05	0.0188945	0.00424512	0.00246027	
co	re	21643	0.0302653	0.549422	0.368073	4.29218e-08	0.00748853	0.000817539	0.000809417.	
plu	unger	6240	0.0162389	0.578949	0.303458	1.20527e-08	0.00594538	0.000362326	0.000659153.	
Re	egion	25688	0.0344636	5.41549	1.11704	1.14458e-07	4.02986	0.0206769	0.100657	
					Export					
					<u>C</u> lose					

1. Project Manager > Solenoid > Analysis > Setup1 우 클릭 > Analyze 클릭

Progress	ч ×
4_solenoid - Solenoid - Setup1: Making Initial Mesh on Local Machine - RUNNING	
	•
Verifying body meshes done.	

- 2. 상단 메뉴 Maxwell 3D > Results > Solution data 클릭
- 3. Force 탭 > plunger가 받는 힘 F(z) = 0.024 N

Solutions: solenoid - Maxwell3DDesign1	_	\times
Simulation: Setup1		
Design Variation:		
Profile Convergence Force Torque Matrix Mesh Statistics		
Decemptor Force 1		
Parameter. Porce in Porce Unit. Inewton		
Pass: 4		
Le Format Funant		
F(x) F(y) F(z) Mag(F)		
Total 1.4109E-05 1.1564E-06 0.024002 0.024002		

- 1. History tree > Plunger 클릭
- 2. 상단 메뉴 View > Visibility > Show Only Selection > Active View
- 3. 상단 메뉴 Edit > Selection Mode > Faces
- 4. plunger의 +Z축 위 표면 선택
- 5. 상단 메뉴 Modeler > List > Create > Face List
- 6. 상단 메뉴 Maxwell 3D > Fields > Calculator...



Fields Calculator			>
Named Expressions			Context: Maxwell3DDesign1
Name Mag_H Mag_B Mag_J H_Vector R Vector Contract Add Library: Load From.	Mag(Smooth(<t Mag(Smooth(<t Mag(Smooth(< Smooth(<hx,h) Smonth(<rx ru<br="">Copy to </rx></hx,h) </t </t 	Delete Delete All o stack To	Solution: Setup1 : LastAdaptive Field Type: Fields Change Variable Values
Scl : 0.276071640737519 Scl : /(Integrate(Surface(F	acelist1), Mag(<bx,< td=""><td>By,Bz>)), Integrate</td><td>e(Surface(Facelist1), 1))</td></bx,<>	By,Bz>)), Integrate	e(Surface(Facelist1), 1))
Pop			
Quantity +	tenerar +	Vec? +	Scal? Value
Geometry		1/x	Matl
Constant 🛨	×	Pow	Mag Write
Number	1		Dot Export
Function	Neg	Trig 🛨	Cross
Geom Settings	Abs	d/d? ±	Divg
Read	Smooth	ſ	Curl
	Complex 🛨	Min 🛨	Tangent
	Domain	Max 🛨	Normal
		\Box	Unit Vec 🛨
		Ln	×Form 🛨
		Log	
		Mean	
		Std	
		Done]

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- 1. Input > Quantity > B
- 2. Vector > Mag
- 3. Input > Geometry > Surface > Facelist1 선택
- 4. Scalar > *f* Integrate
- 5. Input > Number > Scalar > Value : 1 > OK
- 6. Input > Geometry > Surface > Facelist1 선택
- 7. Scalar > **J** Integrate
- 8. General > / (Divide)
- 9. Output > Eval $B_{avg} = \frac{\iint BdS}{\iint 1dS}$

Scl: 0.276071640737519

Scl: /(Integrate(Surface(Facelist1), Mag(<Bx,By,Bz>)), Integrate(Surface(Facelist1), 1))

$B_avg = 0.276 [T]$



Fields Calculator				×
Named Expressions-			Context: Maxwell3DDesign1	
Name	^	1	Solution: Setup1 : LastAdaptive	•
Mag_H Mag_B	Mag(Smooth(<) Mag(Smooth(<)	Delete	Field Type: Fields	-
Mag_J	Mag(Smooth(<	Delete All		
R Vector	Smooth(<bx bu<br="">></bx>			
Add Library: Load Fr ccl : 2.686348647860	Copy to om Save 5E-07	To	Change Variable Values	^
icl : Integrate(Surface)	(Facelist1), Dot(<bx,by,< td=""><td>,Bz>, SurfaceNor</td><td>mal))</td><td>v</td></bx,by,<>	,Bz>, SurfaceNor	mal))	v
Push P		RIDn	Exch Clear Undo	
Input	Lieneral	Scalar	Vector Uutput	1
Geometru		1/4		
Constant +	×	Pow	Mag Write	
Number			Dot Export	1
Function	Neg	Trig 🛨		1
Geom Settings	Abs	d/d? 🛨	Divg	
Read	Smooth	ſ	Curl	
	Complex 生	Min 🛨	Tangent	
	Domain	Max 🛨	Normal	
		\Box	Unit Vec 🛨	
		Ln	XForm 🛨	
		Log		
		Mean		
		Std		
		Done		

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- 1. Input > Quantity > B
- 2. Input > Geometry > Surface > Facelist1 선택
- 3. Vector > Normal
- 4. Scalar > **J** Integrate
- 5. Output > Eval

Scl : 2.6863486478605E-07 Scl : Integrate(Surface(Facelist1), Dot(<Bx,By,Bz>, SurfaceNormal))

Magnetic Flux = 2.686*e(-07) Wb

- 1. History tree > Planes > Global:XZ 선택
- 2. 상단메뉴 Maxwell 3D > Fields > Fields > B > Mag_B
- 3. "Done"

🖃 🖉 Solids
🚊 🚝 copper
i
📄 🚝 Steel
🕂 🖅 core
🗄 🖅 🖉 plunger
📄 🖅 vacuum
🕂 🖅 band
🗄 🖉 Region
🚊 🗆 🗖 Sheets
coil_Section1
Coordinate Systems
Global
📮 🥭 Planes
Clobal:XV
Global:XZ
Global:YZ
🗄 🥔 Lists

Create Field Plot	1	×
Specify Name Mag_B1	Fields Calculator	
Specify Folder	Category: Standard	•
Design: 05_Solenoid	Quantity	In Volume
Context is tied to model window. Edit context by updating the model window's context	Mag_H H_Vector Mag_B	plunger core coil
Solution: Setup1 : Transient	B_Vector Mag_J J_Vector	band Region AllObjects
Field Type: Fields	energy coEnergy appEnergy	
Intrinsic Variables	Ohmic_Loss Total_Loss	
	Volume_Force_Density Surface_Force_Density	
Save As Default		Plot on surface only
Done	Cancel	T Streamline



 도형때문에 자속분포가 잘 안보이면 View 기능을 통해서 모두 숨기고 보면 자속 분포만 볼 수 있음.

Active V 3D M / 1 bar 2 coll 3 cor 4 plut 5 coll	iew Visibility: 20160323_EX - 05_Solenoid - 1 itations Parameters odeler Color Keys Motion Name d a nger Section 1	FieldsReporter Boundaries
Name	lion Sho	w Hide
[tes1a] 9.1547E-01 7.9340E-01 7.937E-01 6.7134E-01 6.1031E-01 5.492E-01 4.825E-01 4.2722E-01 9.616E-01 2.4415E-01 6.30516E-01 2.4415E-01 1.2807E-01 6.308E-02 7.3289E-06		







$$\Phi = \frac{NI}{R_m} = \frac{10*5}{1.91*10^8} = 2.61*10^{(-7)} [Wb]$$
$$B_{avg} = \frac{\Phi}{A_{air}} = \frac{2.61*10^{(-7)}}{1.131*10^{(-6)}} = 0.231 [T]$$
$$F_{plunger} = \frac{B^2 * A_{air}}{2*\mu_0} = 0.024 [N]$$





감사합니다.