

# Lecture 5: Maxwell Transient Solvers

**Fluid Dynamics** 

**Structural Mechanics** 

Electromagnetics

Systems and Multiphysics

ANSYS Maxwell V16 Training Manual



- A. Magnetic Transient Solver
  - a. Selecting the Magnetic Transient Solver
  - b. Material Definition
  - c. Boundary Conditions
  - d. Motion Setup
  - e. Excitations
  - f. Parameters
  - g. Design Settings
  - h. Analysis Setup
  - i. Solution Process
- **B.** Electric Transient Solver
  - a. Selecting the Electric Transient Solver
  - b. Electric Transient Setup
  - c. Analysis Setup

# **ANSYS** A. Magnetic Transient Solver

### **Magnetic Transient Solver:**

- The Magnetic Transient Solver computes time varying magnetic fields
- This is a time domain solver and solves for instantaneous magnetic fields at each time step
- The source of the Time varying magnetic field can be:
  - Arbitrary time-varying voltage or current sources
  - Moving Sources
  - Moving permanent magnets
- Field Quantities can also be strongly coupled with circuit equations to allow arbitrarily defined external circuits
- Magnetic Transient solver does not use Adaptive mesh refinement and thus mesh operations or a Linked Mesh is required to be defined to obtain a sufficient mesh. Mesh Operations are discussed in Lecture 6

# **Magnetic Transient Equations**

Following equations are solved with Transient solver

$$\nabla \times \frac{1}{\sigma} \nabla \times H + \frac{\partial B}{\partial t} = 0$$

$$\nabla \bullet B = 0$$

$$-\nabla \bullet \left( \varepsilon \nabla \frac{\partial \Phi}{\partial t} \right) - \nabla \bullet (\sigma \nabla \Phi) = 0$$
Maxwell 3D
  
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**B** A Constraints of the second second

# **ANSYS** a. Defining a Magnetic Transient Problem

### **Defining Magnetic Transient Solver**

- Specify the Maxwell Magnetic Transient Solver by selecting the menu item Maxwell 2D/3D → Solution Type
- In the Solution Type window, select Magnetic> Transient and press OK

olution Type: Project22 - Maxwell3DD	Solution Type: Project22 - Maxwell2DDe
Magnetic:	Geometry Mode: Cartesian, XY 💌
C Magnetostatic	Manualia
C Eddy Current	Magnetic: C Magnetostatic
<ul> <li>Transient</li> </ul>	C Eddy Current
Electric:	<ul> <li>Transient</li> </ul>
C Electrostatic	Electric:
C DC Conduction	C Electrostatic
Include Insulator Field	C AC Conduction
C Electric Transient	C DC Conduction
OK Cancel	OK Cancel
Maxwell 3D	Maxwell 2D

# **ANSYS** b. Material Definition

### **Transient Material Properties**

In Transient simulation, the following parameters may be defined for a material:
 Relative Permeability :

- Relative Permeability plays a large role in determining the magnetic field solution.
- Relative Permeability,  $\mu_r$  can be Simple or nonlinear and/or Anisotropic

#### **Bulk Conductivity:**

- Used in determining the current distribution in current carrying conductors and induced eddy currents from resulting magnetic field.
- Can be Simple or Anisotropic

#### **Magnetic Coercivity:**

- Defines permanent magnetization of magnetic materials
- Requires magnitude and direction specification.
- Direction specified is with respect to Orientation CS of bodies to which material is assigned

#### **Core Loss Type**

- Can be Electrical Steel, Power Ferrite, or None
- Allows you to define Core Loss coefficients as discussed with Eddy Current Solver

#### **Composition :**

- Can be Solid or Lamination
- Setting Composition to Lamination creates an anisotropic magnetization effect.

	ial Name 5_027			terial Coordi artesian
Prop	perties of the Material			
	Name	Туре	Value	Units
	Relative Permeab	Nonlinear	B-H Curve	
	Bulk Conductivity	Simple	0	siemens/m
	Magnetic Coercivity	Vector		
	- Magnitude	Vector	0	A_per_me.
	<ul> <li>X Component</li> </ul>	Unit Vec	1	
	<ul> <li>Y Component</li> </ul>	Unit Vec	0	
	<ul> <li>Z Component</li> </ul>	Unit Vec	0	
	Core Loss Type		Electrical Steel	w/m^3
	• Kh	Simple	43.5818534070156	
	· Kc	Simple	0.599578467366	
	·Ke	Simple	0	
	· Kdc	Simple	0	
	Mass Density	Simple	7650	kg/m^3
	Composition		Solid	

# **ANSYS** c. Boundary Conditions

### **Assigning Boundary Conditions in 3D**

- Boundary conditions define behavior of the magnetic field at the interfaces or the edges of the problem region
- A boundary can be assigned to a face (or Edge in 2D) from menu item Maxwell
   3D → Boundaries → Assign and select the required boundary assignment

## **Boundary Types**

- Following Boundary types are available for Transient Solvers
  - Maxwell 3D:

#### Maxwell 2D:

- Default: Natural or Neumann
- Zero Tangential H-Field
- Insulating
- Symmetry

- Vector Po
- Vector Potential
  - Balloon
  - Symmetry
  - Master/Slave

- Master/Slave
- The behavior of each boundary remains the same as discussed with Magnetostatic Solver

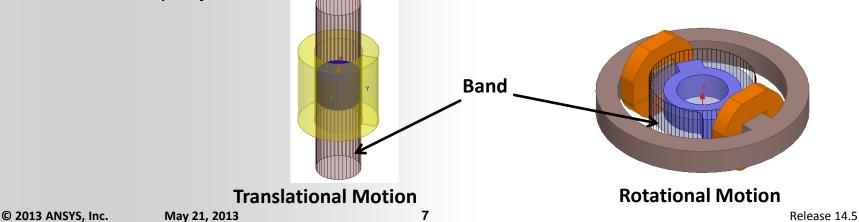
# **ANSYS** d. Motion Setup

# **Motion Setup**

- Time varying magnetic fields solved by the Transient solver can also result from moving excitations or permanent magnets
- Maxwell allows users to define motion types as translation, rotation, or noncylindrical rotation

### **Requirements for Motion Setup**

- All moving objects should be physically separated from stationary objects
- Moving object should be enclosed by a so-called Band object which separates moving parts and stationary part of the geometry
  - In 3D, it is recommended to use a segmented object (Regular Polyhedra) as a Band
- Motion Should not result in intersection or overlap between moving and stationary objects



# ANSYS ... Motion Setup

# **Assign Band**

- Select the object enclosing all moving parts and select the menu item Maxwell
   3D/2D → Model → Motion Setup → Assign Band
- Selected object will be set as a Band and all objects enclosed by it will be assigned as Moving

### **Motion Assignment**

#### **Type Tab**

- Motion Type: Defines motion Translational or Rotational
- Rotational Axis for Rotational motion or Moving Vector for translational vector sets direction of motion

#### Data Tab

- Initial Position: Sets initial position of motion at t=0
- Motion Limit: Sets rotational or translational limits of motion

#### **Mechanical Tab**

- Velocity: Specifies translational or rotational velocity. If mechanical Transient is unchecked, constant velocity is assigned
- **Consider Mechanical Transient:** Maxwell computed forces along with mechanical forces calculated by input parameters are used to determine object motion

Motion Setup				
Type Data Me	chanical			
Motion Type:	C Translation C Rotation	Non-Cylindric	al	
Rotation Axis:	Global::Z • Positive	) Negative	•	
Motion Setup				
Type Data Mechan	ical			
Initial Position:			deg	
🔽 Rotate Limit:				
Negative: 0			deg	
Positive: 360	)		deg	
Motion Setup				
Type Data Mecha	anical			
🔽 Consider Mechanic	al Transient			
Initial Angular Velo	ocity: 0	rpm	•	
Moment of In	ertia: 0	kg m^2		Ca
Dam	ping: 0	N-m-sec/rad		
Load Tor	que: 0	NewtonMeter	-	

# **ANSYS** e. Excitations

## Excitation

- Excitation assignments in the Transient solver are different from the Static Solvers
- The transient solver requires specific information about the coil (such as the number of turns, parallel paths, and resistance) and the type of Excitation (Voltage, Current, or External)
- In general, Excitations thus require a definition of a Coil Terminal assignment, which is then assigned to Winding definition.

# Note: a Permanent Magnet also qualifies as an excitation, and allows for a transient solver solution (e.g. with motion).

# Coil Terminal ("Coil" in 2D)

- Coil terminals are defined to designate the cross sectional faces of the 3D conductors.
- Terminal assignment can be internally located 2D sheet for closed loop or the boundary faces of the Conduction path
- The Coil Terminal defines the direction of current and number of conductors in a conduction path
- Coil Terminal can be added by selecting the 2D sheet object and selecting from the menu item Maxwell 3D
   → Excitations → Assign → Coil Terminal

Coil T	erminal Excitation	
	Name:	CoilTerminal1
	Parameters	
	Number of Conductors:	100
		Swap Direction

# **ANSYS** ... Excitations

# Winding

- Winding definitions determine how the coils are connected and the type of source (Voltage, Current, External Circuit)
- − Winding can be added from the menu item Maxwell 3D → Excitations → Add Winding
- A winding can be Solid or Stranded
  - Stranded winding does not compute Eddy Current in conduction path
- Maxwell allows users to define three types of windings

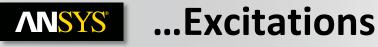
#### **Current Winding**

- Defines Specified current through the conduction path
- Current can be constant or a function of time

#### **Voltage Winding**

- Defines Specified voltage across the coil terminals
- Voltage definition along with Resistance and inductance definition is used to evaluate current through the winding
- Voltage can be constant or function of time

Winding	
Name: Parameters- Type: Current	Winding1       Current       I0"sin(2"pi*50"time)
Winding	
General Defaul	ts
Name:	PhaseA
Parameters	,
Туре:	Voltage 💽 C Solid 🖲 Stranded
Initial Curre	ent 0
Resistance	e: 0.00719351 ohm 💌
Inductanc	e: 3.73393e-005
Voltage:	326.599 * sin(2*pi*50*time+
Number of	parallel branches: 6



# Winding (Contd..)

#### External

- External winding type enables users to assign excitations directly from either the Maxwell Circuit Editor, or Simplorer (see Maxwell 2D/3D → Design Settings)
- From the Menu, select Maxwell → Excitations →
   External Circuit → Edit External Circuit, click
   on Edit Circuit... to launch the Maxwell Circuit Editor.
- Name of the winding representing Conduction path in circuit solver should be same as Name defined in Maxwell

Winding		
General Defaults		
Name:	Winding_A	
Parameters		
Туре:	External 💌	C Solid 🖲 Stranded
Initial Current	0	•

25ohm L	Winding A	Edit External Circuit
+ 100V LabelID=V3 +	Export Netlist	Winding Information Available Inductors   Source Type   Parameter Values   Circ ()
LabelID=IVotmeter6		Below is a list of the externally connected windings you have setup in your model.           Winding Name         Has Inductor in Circuit         Inductor Name
10V LabelID=V4		Winding_A IV LWinding_A
Maxwell Ciruit Editor		Import Netlist from Maxwell $3D/2D \rightarrow$ External Circuit $\rightarrow$ Edit External Circuit

### **Add Coil Terminals to Winding**

- In order to completely define the excitations, the Coil terminals are added to the Winding definition
- Right Click on Project Manager window and select Assign Coil Terminals



## **Setting Eddy Effects**

- − Eddy Effects can be set from the menu item Maxwell 3D/2D → Excitations → Set Eddy Effects
- Induced eddy current calculations can be enabled or disabled for an object

S	Set Eddy Effect				
	Use checkboxes to turn on/off eddy effect settings:				
	Object Eddy Effect				
		LV_A	~		
		LV_B	✓		

### **Setting Core Loss**

- − Core Loss calculations can be assigned from the menu item Maxwell 3D/2D →
   Excitations → Set Core Loss
- If Core Loss is enabled for an object, Eddy effects should be disabled for it as Core loss includes Eddy losses
- Core Loss properties must be defined in material definition as discussed with Eddy Current Solver in Lecture3
- Advanced tab enables to consider impact of Core loss on Solved magnetic fields

iet Cor	e Loss			
Genera	Advanc	ed		
set	ting will on inition in th	y take effect if the ot e material library.	re loss settings. Pleas bject has a correspond	
	Object	Core Loss Setting	Defined in Material	
	LV_A			
	LV_B			
	LV_C			
	core	<b>v</b>	V	
4.0				40

Set Core	Loss
General	Advanced
	Consider core loss effect on field



#### Parameters

- Force and Torque parameters can be assigned in Transient Solver
- A parameter can be added by selecting the required object and selecting menu item Maxwell 3D/2D → Parameters → Assign

Force:
Calculates force acting on assigned object
Only Virtual forces can be assigned
Force Setup
Force Post Processing
Name: Force1
Туре
C Lorentz

#### **Torque:**

- Calculates torque on assigned object
- Only Virtual Torque can be assigned

Torque		Þ	<
Name:	Torque1		
- Type-			
	🖲 Virtual		
	C Lorentz		
_Axis_			
G	lobal::Z	•	
e	Positive	C Negative	

Note: If motion setup is assigned, force and torque calculations are assigned by default for the moving objects and computed at all time steps. User can plot these values using XY Plots to view parameters values

# ANSYS g. Design Settings

### **Design Settings**

Design Settings can be accessed from menu item Maxwell 3D/2D → Design Settings

#### **Symmetry Multiplier**

- When partial Geometry is modeled using Symmetry or Master/Slave boundary, Symmetry Multiplier is required to be specified to consider the impact of full geometry
- All specified Input parameters and reported output parameters (except field calculator quantities) are scaled based on assigned Symmetry Multiplier

#### Model Depth (2D XY Designs)

- Where user sets the length of the model perpendicular to XY plane
- Outputs are scaled based on length specified

#### **Advanced Product Coupling Tab**

Enables Maxwell-Simplorer Transient cosimulation

#### **Advanced Product Coupling Tab**

• Enables Inductance matrix computation for Transient Solver

3D Design Settings					
	reserve Transient Solution	Set Material Override			
Advanced Product Coupling	Symmetry Multiplier	Matrix Computation			
Symmetry Multiplier: 6					

_						
2	2D Design Settings					
	Material Thresholds Symmetry Multiplier Advanced Product Coupling Background Matrix Computation Model Depth Preserve Transient Solution					
	Model Depth: 1 meter 💌					
3D	) Design Settings					
	Material Thresholds Preserve Transient Solution Set Material C Advanced Product Coupling Symmetry Multiplier Matrix Comp					
	✓ Enable transient-transient link with Simplorer					
30	3D Design Settings					
F	Material Thresholds Preserve Transient Solution Set Material Advanced Product Coupling Symmetry Multiplier Matrix Com					

# ANSYS h. Analysis Setup

### **Solution Setup**

- The solution setup defines the parameters used for solving the simulation
- A Solution Setup can be added from the menu item Maxwell 3D/2D → Analysis
   Setup → Add Solution Setup

#### **General Tab**

- Name: sets the Name of the setup. Users can have multiple setups in the same design by repeating the procedure
- **Stop Time:** Defines transient simulation time at which simulation will stop
- Time step: Discrete steps of time used in transient simulation

#### Save Fields Tab

- Sweep Setup (Type, Start, Stop, Step): Defines time steps at which field is saved
- Save Fields: Saves the fields for defined time steps
- Add to List >>: Places sweep definition in the Sweep List (the Sweep List is displayed in the right panel).
- Edit any entries in the Sweep List to adjust solution frequencies or whether to save fields at specific frequencies in the list.

Solve Setup		
General Save Fields Advanced	Solver Expression Cache	Defaults
Name:	Setup1	🔽 Enabled
Transient Setup		
Stop time:	0.01	s 💌
Time step:	0.002	s <b>•</b>

Solv	ve Set	up								
Ge	eneral	Sav	e Fields	Adv	anc	ed	Solver	Expression Ca	ache	Defaults
	Sweep	p Set	up ——	-			1			Time
	Туре:		Linear S	itep		•	A	dd to List >>		Os
	Start:		0	s		•	Be	place List >>		0.005s
										0.01s
	Stop:		0.01	s		•				
	Step 9	Size:	0.005	s		•	Add	d Single Point		
							Del	ete Selection		
								Clear All		
							Und	o Last Change		



# **ANSYS** ... Analysis Setup

### Solution Setup

#### **Advanced Tab**

- **Control Program:** Used to dynamically adjust parameters and control the simulation
- **Demagnetization Option:** Allows the permanent demagnetization to be determined from the Nonlinear B-H curve or to use demagnetized values From Link - where the linked solution must the option "Compute Data for Link - Demagnetized operating points" checked and must have the exact same geometry
- **Continue from a previously solved setup**: Enables to continue the solution from a linked Maxwell design setup
- **Import Mesh:** Allows the initial mesh to be imported from another solution – the linked solution must have the exact same geometry as the current simulation. Setup Link must be defined when selecting From Link or Import Mesh.

#### **Solver Tab**

- Nonlinear Residual: Defines how precisely the nonlinear solution must define the B-H nonlinear operating points
- **Output Error:** Calculates percent energy error and provides • measure of convergence of total field solution at each time step.

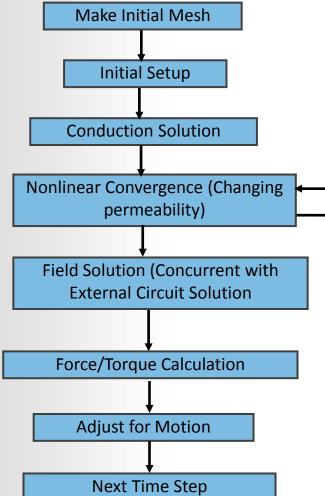
olve Setup						
General Save Fields Advanced Solver Expressi	on Cache Defaults					
Control Program						
Use Control Program						
Arguments:	Configure					
🗖 Call after last time	e step for post processing					
Demagnetization Option	Demagnetization Option					
Nonlinear B-H curve     Setup Link						
C Use dynamic magnetization data	Setup Link					
Import Option						
$\square$ Continue from a previously solved setup	Setup Link					
🔲 Import mesh	Setup Link					
Compute Data For Link						
Dynamic demagnetization distribution						

So	lve Setup
	eneral   Save Fields   Advanced   Solver   Expression Cache   Defaults
	Nonlinear Residual: 0.005
	Cutput error



#### **Transient Solution Process**

A Solution process can be launched form the menu item Maxwell 3D/2D →
 Analyze All



# **ANSYS** B. Electric Transient Solver

### **Electric Transient Solver:**

- Electric Transient Solver computes time varying electric fields
- The source of the Time varying electric field can be a time-varying potential, charge distribution or applied currents
- Electric Transient solver is available only with Maxwell 3D
- Electric Transient solver uses adaptive time stepping approach where time step size is varied based on the solution convergence
- Following equations are solved with Transient solver
- Electric Transient solver does not use Adaptive mesh refinement and thus mesh operations are required to be defined to obtain a better mesh
  - Mesh Operations are discussed in Lecture 6

### **Electric Transient Equations**

- Following equations are solved with Transient solver

$$-\nabla \bullet \left( \varepsilon \nabla \frac{\partial \Phi}{\partial t} \right) - \nabla \bullet (\sigma \nabla \Phi) = 0$$

# **ANSYS** a. Defining an Electric Transient Problem

#### **Defining Electric Transient Solver**

- − Specify the Electric Transient Solver by selecting the menu item Maxwell 3D →
   Solution Type
- In Solution type window, select Electric > Electric Transient and press OK

Solution Type: Project22 - Maxwell3DD		
Magnetic:		
C Magnetostatic		
C Eddy Current		
C Transient		
Electric:		
C Electrostatic		
C DC Conduction		
Include Insulator Field		
Electric Transient		
OK Cancel		

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# **ANSYS** b. Electric Transient Setup

### **Material Properties**

Material properties required for Electric Transient solver are same as

Mat	erial Name			Material Coordi
Va	cuum			Cartesian
D.	enerties of the Material			
	roperties of the Material	Turce	Maha	Huitz
P	roperties of the Material Name Relative Permittivity	Type Simple	Value	Units

# **Boundary Types**

- Following Boundary types which were discussed with Electrostatic solver are also available for Electric Transient Solvers
  - Default: Natural or Neumann
  - Insulating
  - Symmetry
  - Master/Slave

### Excitations

- All the excitations that can be assigned with Electrostatic and DC conduction solver can also be assigned with Electric Transient Solver
  - Voltage

• Volume Charge Density

- Charge
- Floating

May 21, 2013

• Sink

Current

All the above excitations can be specified as a function of time

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# **ANSYS** c. Analysis Setup

## **Solution Setup**

A Solution Setup can be added from the menu item Maxwell 3D → Analysis
 Setup → Add Solution Setup

#### **General Tab**

- Name: sets the Name of the setup. Users can have multiple setups in the same design by repeating the procedure
- **Stop Time:** Defines the time interval for which the solution is calculated
- Initial Time Step: Defines time step size used by solver at the start of the solution
- Maximum Time Step: Defines maximum size of the time step used by solver
- Save Fields: Enables to save fields at each time step

#### Solver Tab

- Temporal Tolerance: Defines tolerance in time sizes
- Initial Condition: Can be a preset Value or the solution of a Static Field. Setup Link tab can be used to link a static field
- Import Mesh: Allows the initial mesh to be imported from another solution – the linked solution must have the exact same geometry as the current simulation.

Solve Setup		
General Solver Expression	n Cache Defaults	
Name: Setup1	🔽 Enabled	
Time Steps		
Stop Time:	100	s 💌
Initial Time Step:	0.01	s <b>•</b>
Maximum Time Step:	5	s <b>•</b>
🔽 Save Fields		

Solve Setup					
General Solver Express	sion Cache Defaults				
Temporal Tolerance: 0.005					
/					
• Value	V				
C Static Field	Setup Link				
Import mesh	Setup Link				