ANSYS

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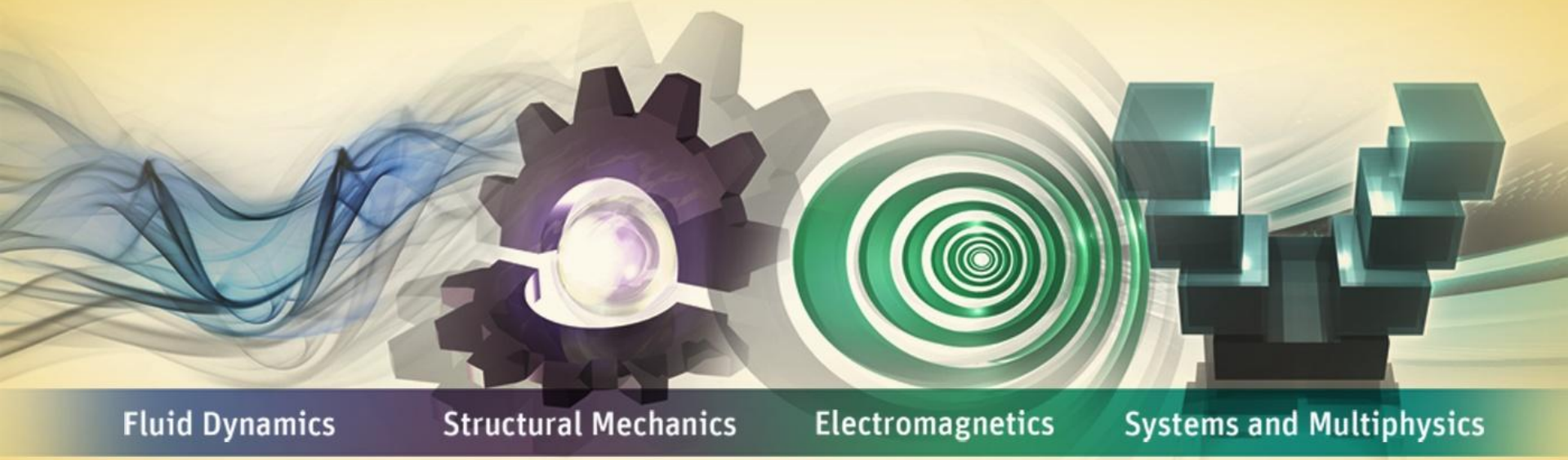
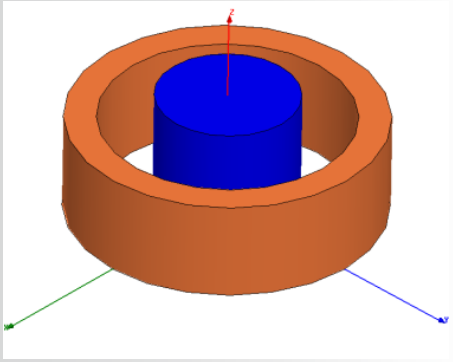
Workshop 10:
Basic Parametric Analysis



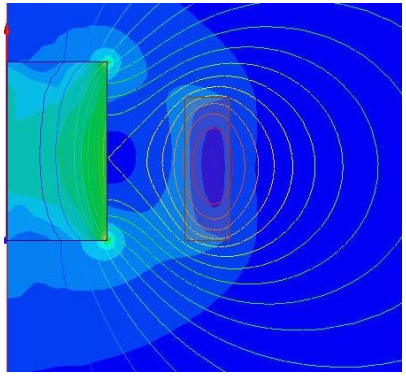
ANSYS Maxwell 2D V16

About Workshop

- **Parametric study using a coil and Iron slug**
  - This workshop describes the steps required to setup a parametric analysis offered through Optimetrics.
  - An RZ Magnetostatic problem will be used to demonstrate the setup of a parametric solution using Optimetrics in Maxwell 2D. The coil current and the dimensional length of an iron slug will be varied and the force on the slug will be observed.



3D Geometry: Coil and Iron Slug

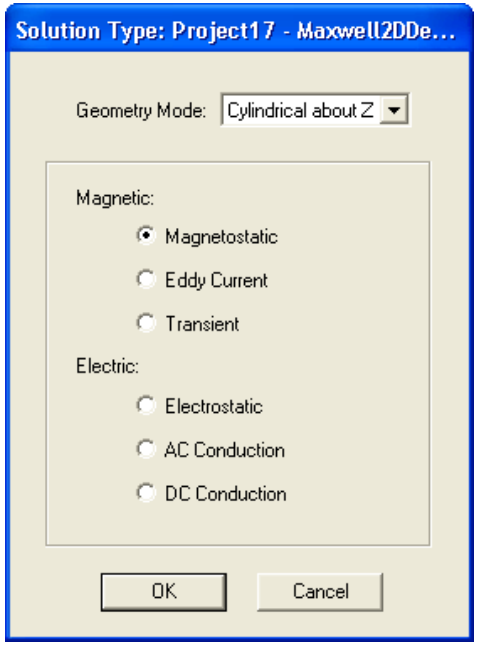


2D Flux Lines and Flux Density

Problem Setup

- **Create Design**
  - Select the menu item ***Project → Insert Maxwell 2D Design***, or click on the icon

- **Set Solution Type**
  - Select the menu item ***Maxwell 2D → Solution Type***
  - Solution Type Window:
    1. Geometry Mode: **Cylindrical about Z**
    2. Choose **Magnetic > Magnetostatic**
    3. Click the **OK** button

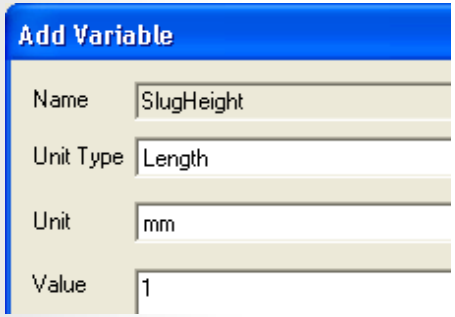


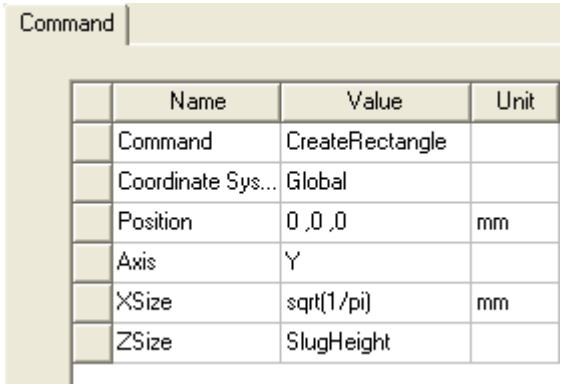
Create Model

- **Create Coil**
  - Select the menu item ***Draw → Rectangle***
    1. Using the coordinate entry fields, enter the position of rectangle
       - **X: 1, Y: 0, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 0.25, dY: 0, dZ: 0.8**, Press the **Enter** key
  - Change the name of resulting sheet to **Coil** and color to **Orange**
  - Change the material of the sheet to **Copper**
- **Create Slug**
  - Select the menu item ***Draw → Rectangle***
    1. Using the coordinate entry fields, enter the position of rectangle
       - **X: 0, Y: 0, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 0.5, dY: 0, dZ: 1**, Press the **Enter** key
  - Change the name of resulting sheet to **Slug** and color to **Blue**
  - Change the material of the sheet to **Steel_1008**

Add Parameter SlugHeight

- **Parameterize Slug**
  - Expand the history tree for the sheet **Slug**
  - Double Click on the command **CreateRectangle** to open Properties window,
  - In Properties window,
    - Change Xsize to **sqrt(1/pi)**
    - Change Zsize to **SlugHeight**
    - Press **Enter**
  - In Add Variable window,
    - Unit: **mm**
    - Value: **1**
    - Press **OK**



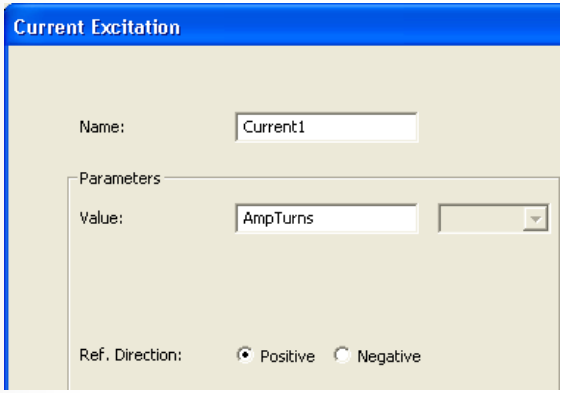


Note: By defining a variable name (SlugHeight) it becomes a design variable. The design variables are accessible by selecting menu item Maxwell 3D → Design Properties. If variable name is appended by symbol $, it will be defined as project variable and can be accessed across the designs.

Parameter for Xsize is defined using the predefined constant, pi, and an equation that calculates equivalent 2D cross-section of a 1mm² slug which was used in the 3D Exercise.

Assign Excitations

- **Assign Excitations**
  - Select the sheet **Coil** from history tree
  - Select the menu item ***Maxwell 2D → Excitations → Assign → Current***
    - Value: **AmpTurns**
    - Ref. Direction: **Positive**
    - Press **OK**
  - In Add Variable window,
    - Value: **100**
    - Press **OK**



- **Create Simulation Region**
  - Select the menu item ***Draw → Region***
  - In Region window,
    1. Pad all directions similarly: ☑ **Checked**
    2. Value: **500**
    3. Press **OK**

Note: Region will not be created in Negative X direction due to RZ-symmetry about the Z-axis.

Assign Boundary and Parameters

- **Assign Boundary to Region Edges**
  - Select the object **Region** from history tree
  - Select the menu item ***Edit → Select → All Object Edges***
  - Select the menu item ***Maxwell 2D → Boundaries → Assign → Balloon***
  - In Balloon Boundary window
    - Press **OK**

Note: On symmetry axis, "Balloon Boundary" assignment is automatically skipped, This can also be achieved by selecting the edges of region which are not on symmetry axis.

- **Assign Force Parameter**
  - Select the object **Slug** from history tree
  - Select the menu item ***Maxwell 2D → Parameters → Assign → Force***
  - In Force Setup window,
    - Name: **SlugForce**
    - Press **OK**

Analysis Setup

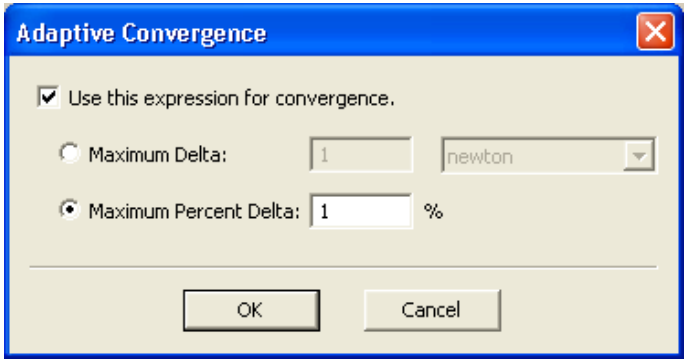
Note: As we will be running parametric analysis for Force Value, we need to ensure that the solver calculates force values accurately. This can be achieved by using Force Value as a solution Convergence criteria. Adding Expression Cache in Solution Setup will enable convergence computation for added parameters.

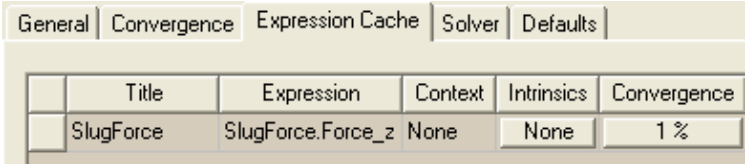
- **Create Analysis Setup**
  - Select the menu item ***Maxwell 2D → Analysis Setup → Add Solution Setup***
  - In Solve Setup window,
    - **General tab**
      - Maximum Number of Passes: **10**
      - Percentage Error: **0.5**
    - Press **OK**

Note: Above setup will be modified in the next setup to add Expression Cache. Expression cache addition is enabled only after the creation of Analysis Setup.

Analysis Setup (*Contd…*)

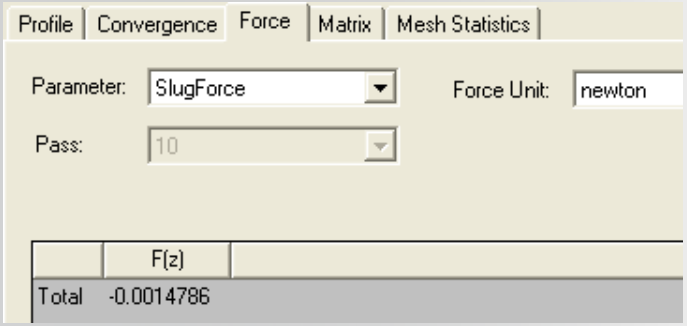
- **Modify Analysis Setup**
  - Expand the Project Manager tree to view **Analysis**
  - Double click on **Setup1** to edit its parameters
  - In Solve Setup window,
    - **Expression Cache** tab
      - Select **Add**
      - In Add to Expression Cache window,
        - Category: **Force**
        - Quantity: **SlugForce.Force_z**
        - Select **Add to Calculation** and **Done**
      - Change Title to **SlugForce**
      - Select the tab in **Convergence** column
      - In Adaptive Convergence window,
        - Use this expression for convergence: ☑ **Checked**
        - Maximum Percentage Delta: **1**
        - Press **OK**
      - Press **OK** to close Solve Setup window

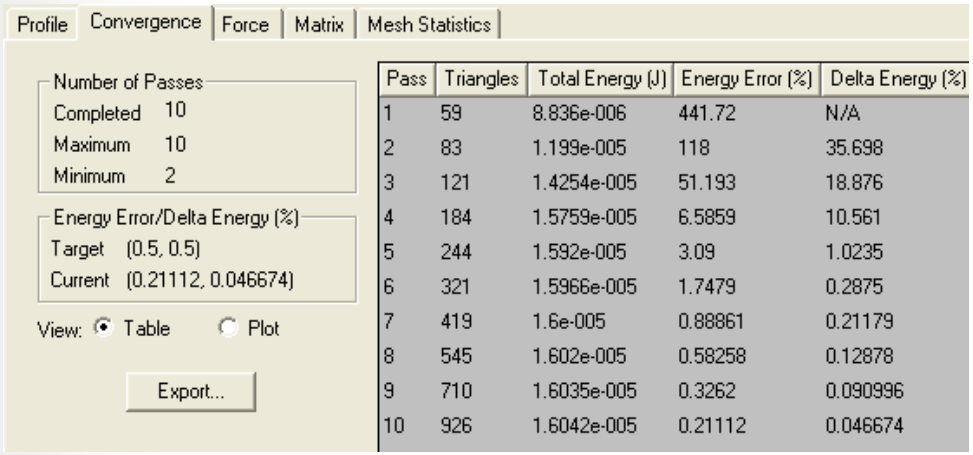




Analyze

- **Start the solution process:**
  - Select the menu item ***Maxwell 2D → Analyze All***
- **View Solution Information**
  - Select the menu item ***Maxwell 2D → Results → Solution Data***
    - To View Convergence
      - Select **Convergence** tab
    - To View Force Values
      - Select the **Force** tab

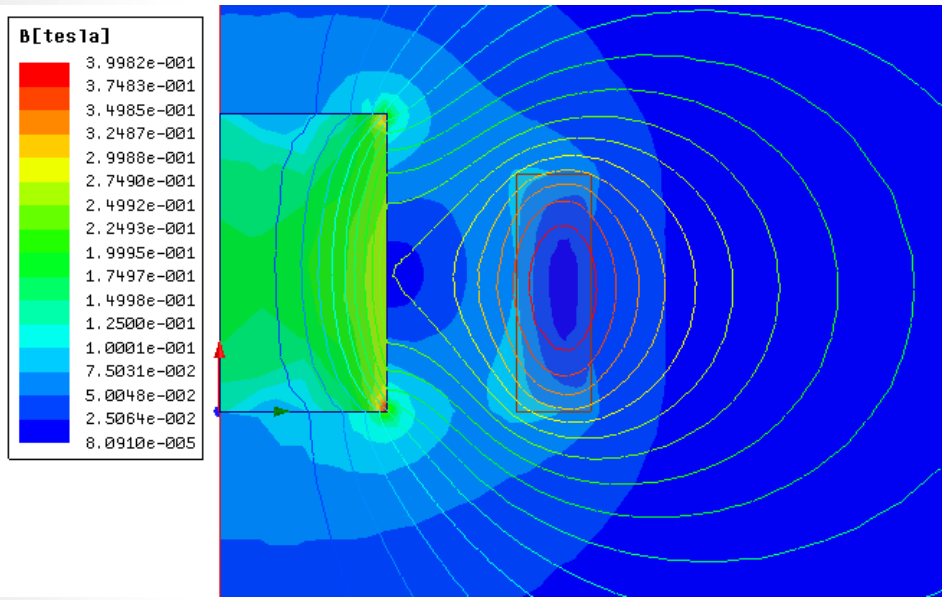




Pass	Triangles	Total Energy (J)	Energy Error (%)	Delta Energy (%)
1	59	8.836e-006	441.72	N/A
2	83	1.199e-005	118	35.698
3	121	1.4254e-005	51.193	18.876
4	184	1.5759e-005	6.5859	10.561
5	244	1.592e-005	3.09	1.0235
6	321	1.5966e-005	1.7479	0.2875
7	419	1.6e-005	0.88861	0.21179
8	545	1.602e-005	0.58258	0.12878
9	710	1.6035e-005	0.3262	0.090996
10	926	1.6042e-005	0.21112	0.046674

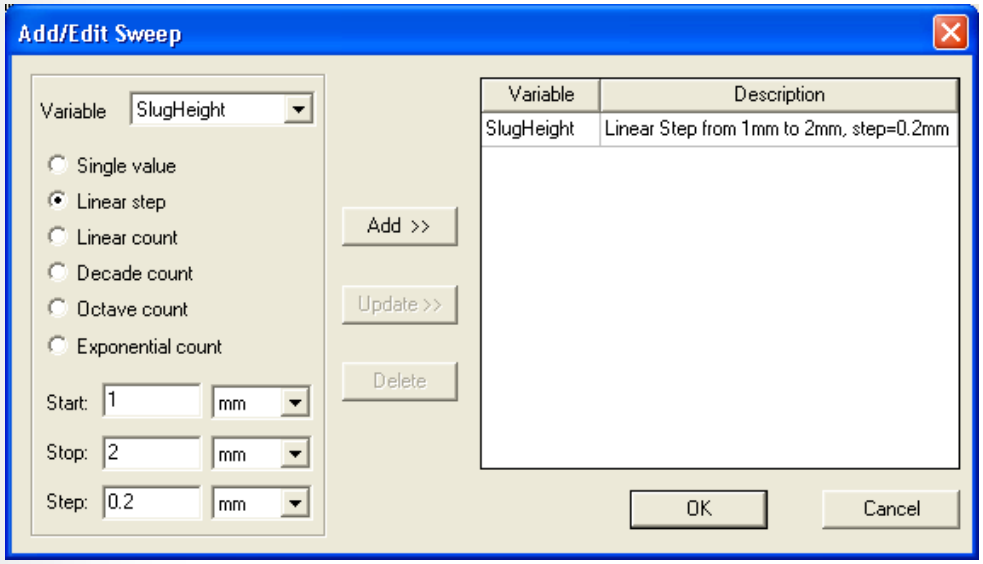
Plot Flux Results

- **Plot Flux**
  - Select the menu item ***Edit → Select All***
  - Select the menu item ***Maxwell 2D → Fields → Fields → B → Mag_B***
  - In Create Field Plot window,
    - Press **Done**
  - Select the menu item ***Edit → Select All***
  - Select the menu item ***Maxwell 2D → Fields → Fields → A → Flux_Lines***
  - In Create Field Plot window,
    - Press **Done**



Parametric Sweep Setup

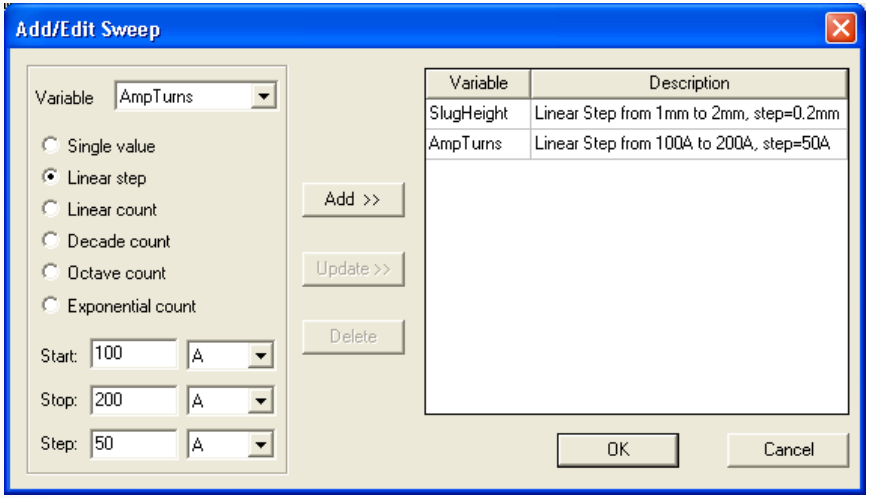
- **Launch Setup Sweep Analysis window,**
  - Select the menu item ***Maxwell 2D → Optimetrics Analysis → Add Parametric***
- **Add Parameter Sweep for SlugHeight**
  - In Setup Sweep Analysis window, select **Add**
  - In Add/Edit Sweep window,
    - Variable: **SlugHeight**
    - Linear Step: ☑ **Checked**
    - Start: **1mm**
    - Stop: **2mm**
    - Step: **0.2mm**
    - Select **Add**



Note: Do not close the Add/Edit Sweep window

Parametric Sweep Setup (*Contd…*)

- **Add Parameter Sweep for AmpTurns**
  - In Add/Edit Sweep window,
    - Change Variable to **AmpTurns**
    - Linear Step: ☑ **Checked**
    - Start: **100 A**
    - Stop: **200 A**
    - Step: **50 A**
    - Select **Add**
    - Press **OK** to close Add/Edit Sweep window

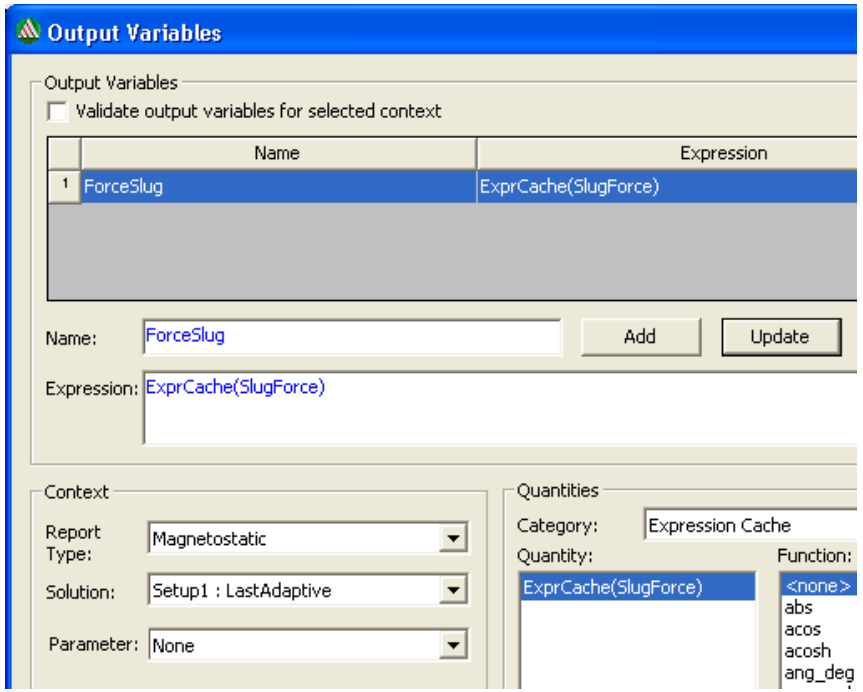


- **View Added Parametric Variations**
  - In Setup Sweep Analysis window,
    - Change tab to **Table** to inspect the combination of solutions that have been created. There should be 18 solutions since we defined 6 variations of SlugHeight and 3 variations of AmpTurns.

Note: Do not close the Setup Sweep Analysis window

Parametric Sweep Setup (*Contd…*)

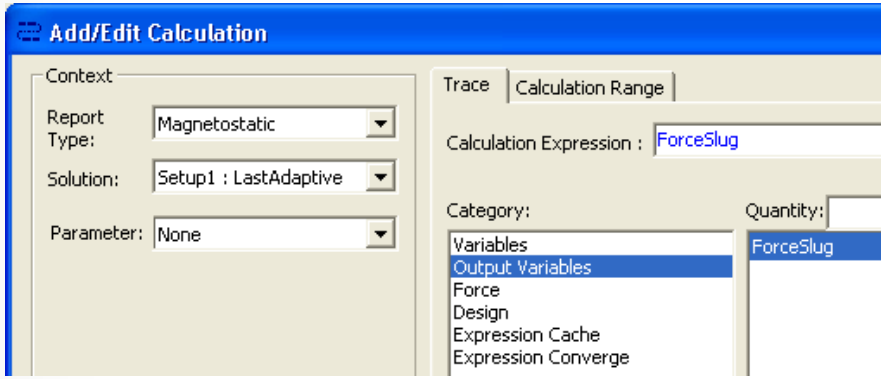
- **Setup Output Parameters: Create Output Variable**
  - In Setup Sweep Analysis window,
    - On **Calculations** tab, select **Setup Calculations**
    - In Add/Edit Calculation window, Select **Output Variables**
    - In Output Variables window,
      - Category: **Expression Cache**
      - Quantity: **ExprCache(SlugForce)**
      - Select **Insert Into Expression**
      - Name: **ForceSlug**
      - Select **Add**
      - Select **Done**



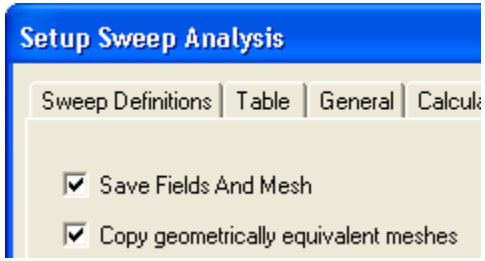
Note: You will now return to Add/Edit Calculations window. Do not close this window

Parametric Sweep Setup (*Contd…*)

- **Setup Output Parameters: Add Output Variable**
  - In Add/Edit Calculation window,
    - Category: **Output Variables**
    - Quantity: **ForceSlug**
    - Select **Add Calculation**
    - Select **Done** to close window

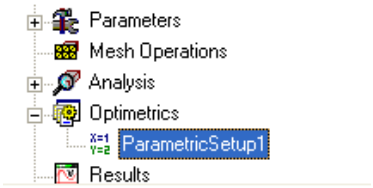


- **Setup Options**
  - In Setup Sweep Analysis window,
    - Select **Options** tab on Setup Sweep Analysis window
      - Save Fields and Mesh: ☑ **Checked**
      - Copy geometrically equivalent meshes: ☑ **Checked**
    - Click **OK** to close



Solve the Parametric Setup

- **Solve Parametric Setup**
  - In Project manager window, expand the tree for **Optimetrics**
  - Right click on the tab **Parametric Setup1** and select **Analyze**



Note: the solving criteria is taken from the nominal problem, Setup1. Each parametric solution will re-mesh if the geometry has changed or the energy error criteria is not met as defined in Setup1.

- **View the Results of Parametric Sweep**
  - In Project manager window, expand the tree for **Optimetrics**
  - Right click on the tab **Parametric Setup1** and select **View Analysis Results**
  - In Post Analysis Display window,
    1. View: Select **Table** to view results in tabular form

Result | Profile

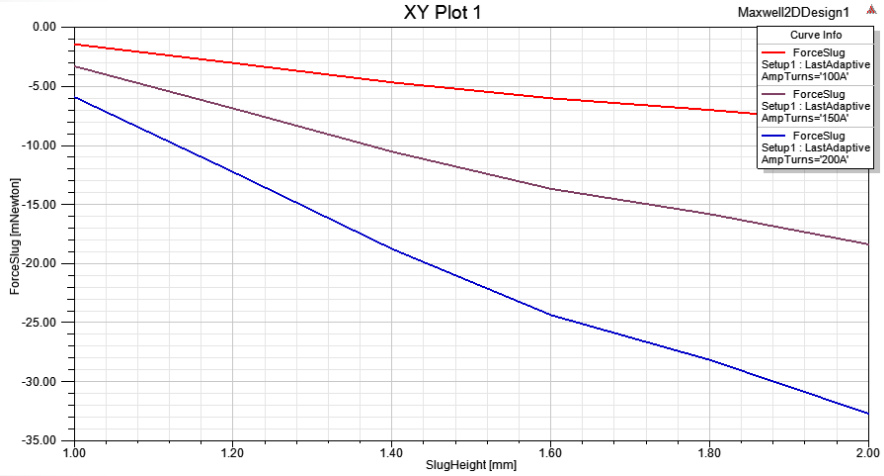
View: Table Show complete output name

Plot

Variation	AmpTurns	SlugHeight	ForceSlug: None
1	100A	1mm	-0.0014785610617180...
2	150A	1mm	-0.0033280830868874...
3	200A	1mm	-0.0059181428038168...
4	100A	1.2mm	-0.0030637163402462...
5	150A	1.2mm	-0.0068963250654453...
6	200A	1.2mm	-0.0122635432063881...
7	100A	1.4mm	-0.0046990745784321...

Create XY Plot

- **Plot Force vs. AmpTurns vs. SlugHeight**
  - Select the menu item ***Maxwell 2D → Results → Create Magnetostatic Report → Rectangular Plot***
  - In report window,
    1. Primary Sweep: **SlugHeight**
    2. X : **Default**
    3. Category: **Output Variables**
    4. Quantity: **ForceSlug**
    5. Select the **Families** tab**:**
       - Ensure that that **AmpTurns** is selected as the Sweeps variable.
    6. Select **New Report**
  - The Plot should appear as shown in image
  - Right click on the plot and select export to export the data in text file



Create 3D Plot

- **Create a 3D plots**
  - Select the menu item ***Maxwell 2D → Results → Create Magnetostatic Report → 3D Rectangular Plot***
  - In Reports window,
    1. Category: **Output Variables**
    2. Quantity: **ForceSlug**
    3. Press **New Report** and **Done**