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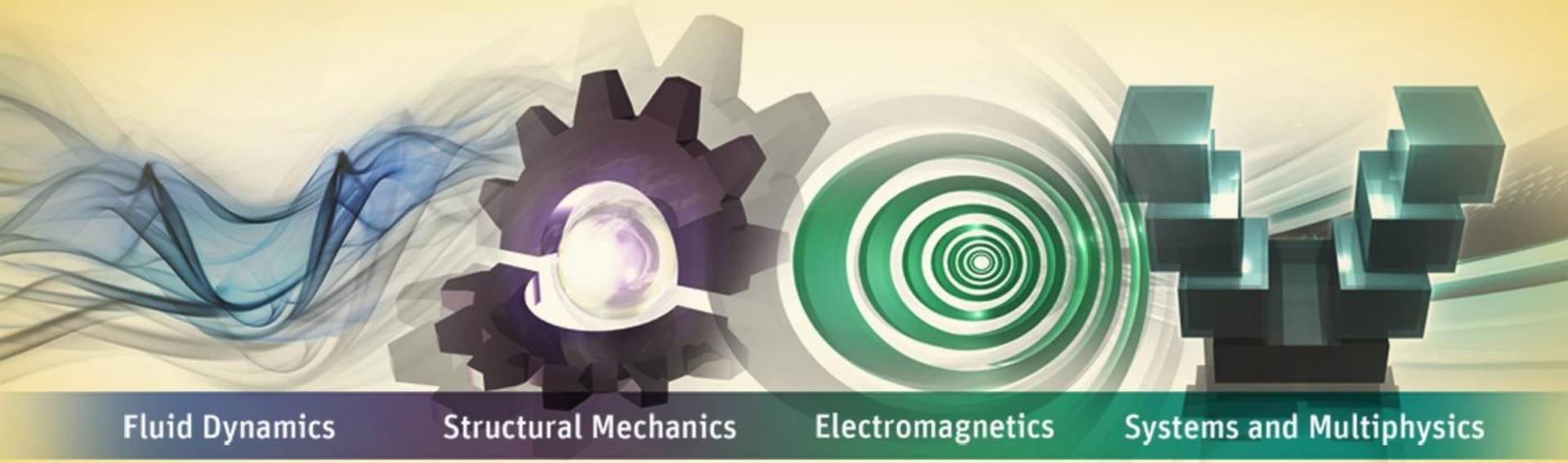
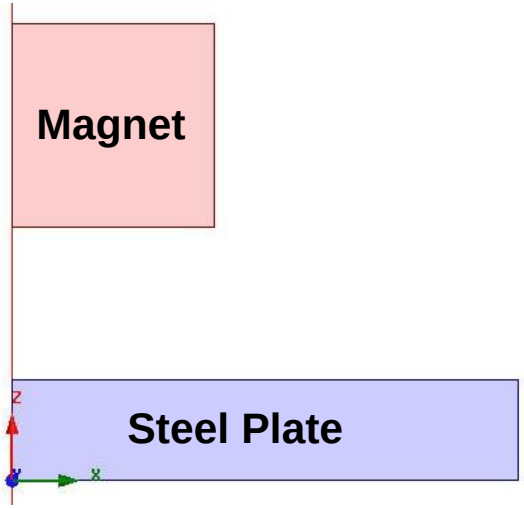
Workshop 11:
Basic Optimetrics Analysis



ANSYS Maxwell 2D V16

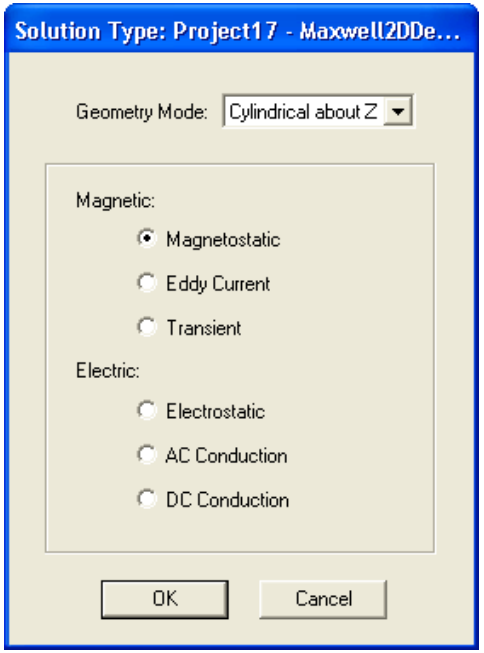
About Workshop

- **Puck Magnet Attractor**
  - Optmietrics is a powerful tool for obtaining optimized values of input parameters for minimum/maximum/required value of Output parameters
  - This example describes how to create and optimize a puck magnet producing an optimal force on a steel plate using the 2D RZ Magnetostatic solver and Optimetrics in the ANSYS Maxwell 2D Design Environment.
  - The optimization obtains the desired force = 0.25N by varying the air gap between the plate and the puck using a local variable.



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

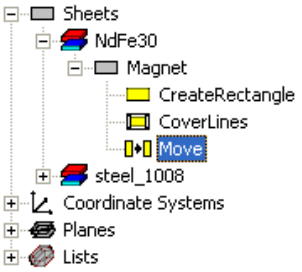


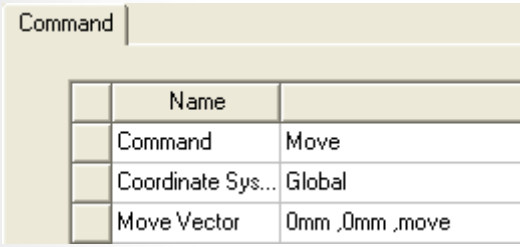
Create Model

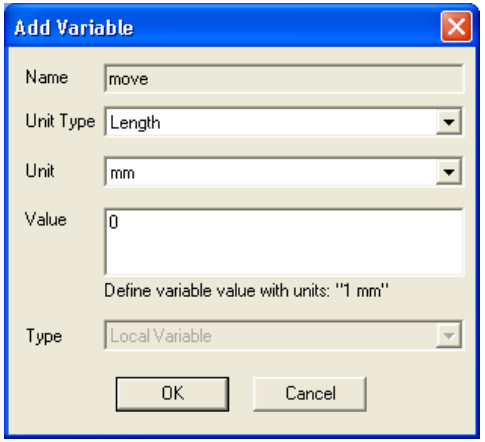
- **Create Plate**
  - Select the menu item ***Draw → Rectangle***
    1. Using the coordinate entry fields, enter the position of rectangle
       - **X: 0, Y: 0, Z: 0**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 5, dY: 0, dZ: 1**, Press the **Enter** key
  - Change the name of resulting sheet to **Plate** and color to **Blue**
  - Change the material of the sheet to **Steel 1008**
- **Create Magnet**
  - Select the menu item ***Draw → Rectangle***
    1. Using the coordinate entry fields, enter the position of rectangle
       - **X: 0, Y: 0, Z: 2**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the opposite corner
       - **dX: 2, dY: 0, dZ: 2**, Press the **Enter** key
  - Change the name of resulting sheet to **Magnet** and color to **Red**
  - Change the material of the sheet to **NdFe30**

Create Parameter for Magnet Motion

- **Create Magnet Motion**
  - Select the sheet **Magnet** from history tree
  - Select the menu item ***Edit → Arrange → Move***
    1. Using the coordinate entry fields, enter the reference point
       - **X: 0, Y: 0, Z: 2**, Press the **Enter** key
    2. Using the coordinate entry fields, enter the target point
       - **dX: 0, dY: 0, dZ: 0**, Press the **Enter** key
  - Expand the history tree for the sheet **Magnet**
  - Double click on the command **Move** from the tree
  - In Properties window,
    1. Change Move Vector to **0, 0, move**
    2. In Add variable window,
       - Unit Type: **Length**
       - Unit: **mm**
       - Value: **0**
       - Press **OK**
    3. Press **OK** to close Properties window

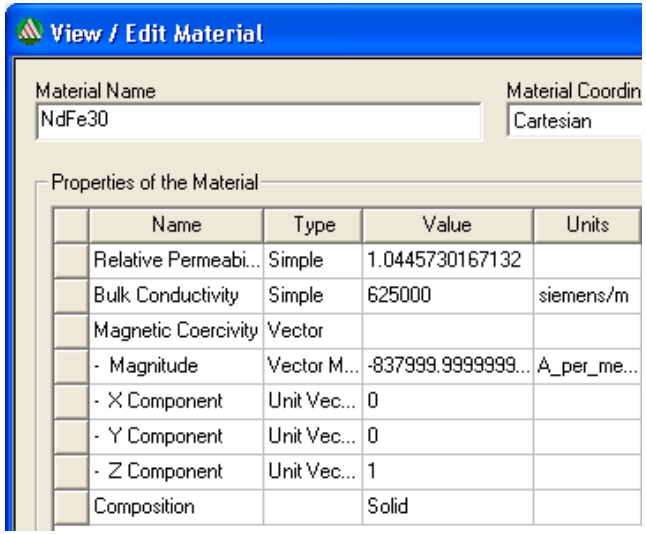






Modify Magnetization Direction for Puck

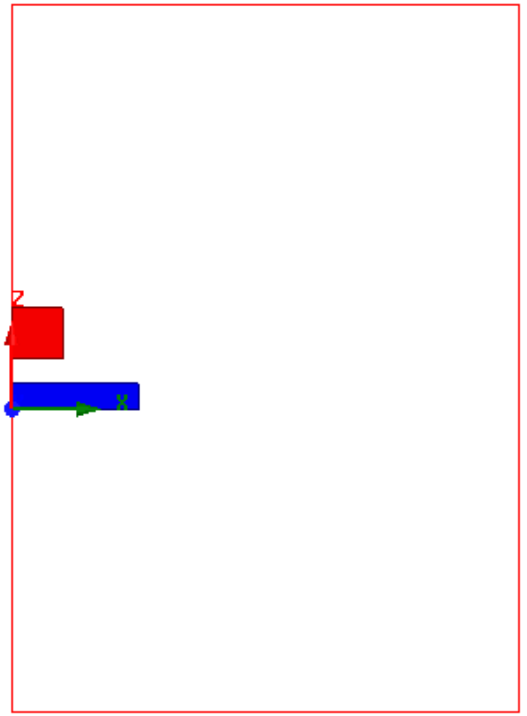
- **Modify Magnetization Direction**
  - Right click on the material **NdFe30** from history tree and select **Properties**
  - In Select Definition window,
    - Ensure that material **NdFe30** is selected
    - Select the button **View/Edit Material**
    - In View/Edit Material window,
      - Change X Component to **0**
      - Change Z Component to **1**
      - Select **Validate Material**
      - Press **OK**
    - Select **OK** to close Select Definition window



Note: The default magnetization direction for NdFe30 is in the X-direction. Since magnetization in the Z-direction is desired for this example, material properties will be changed accordingly

Define Region

- **Create Simulation Region**
  - Select the menu item ***Draw → Region***
  - In Region window,
    1. Pad all directions similarly: ☑ **Checked**
    2. Padding Type: **Percentage Offset**
    3. Value: **300**
    4. 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**
  - Select the sheet **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 Calculation**
  - Select the sheet **Plate** from history tree
  - Select the menu item ***Maxwell 2D → Parameters → Assign → Force***
  - In Force Setup window,
    - Name: **Force1**
    - Press **OK**

Analysis Setup

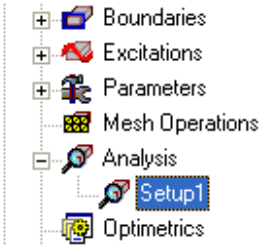
Note: As we will be running Optimetrics Analysis for desired Force Value, we need to ensure that the solver calculates force values accurately. This can be achieved by using Force Value as a solution Convergence criteria. Adding Expression Cache in Solution Setup will enable convergence computation for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

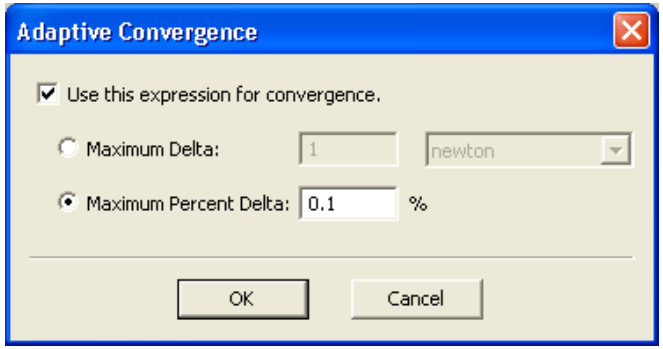
- **Create Analysis Setup**
  - Select the menu item ***Maxwell 2D → Analysis Setup → Add Solution Setup***
  - In Solve Setup window,
    - **General tab**
      - Maximum Number of Passes: **15**
      - Percentage Error: **0.1**
    - Press **OK**

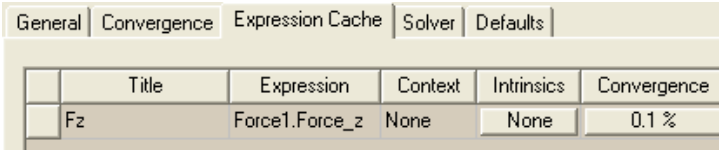
Note: Above setup will be modified in the next setup to add Expression Cache. Expression cache addition is enabled only after the creation of Analysis Setup.

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: **Force1.Force_z**
        - Select **Add to Calculation** and **Done**
      - Change Title to **Fz**
      - Select the tab in **Convergence** column
      - In Adaptive Convergence window,
        - Use this expression for convergence: ☑ **Checked**
        - Maximum Percentage Delta: **0.1**
        - Press **OK**
      - Press **OK** to close Solve Setup window

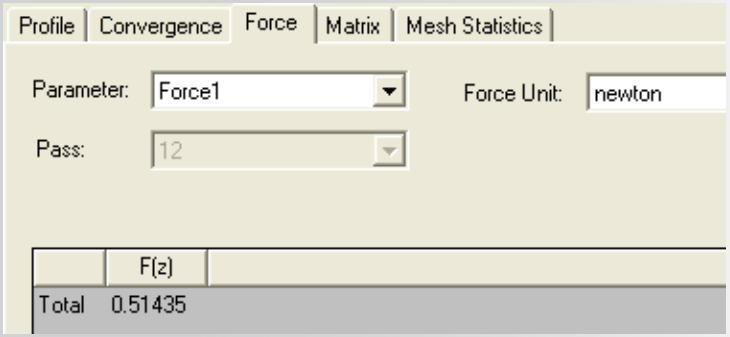


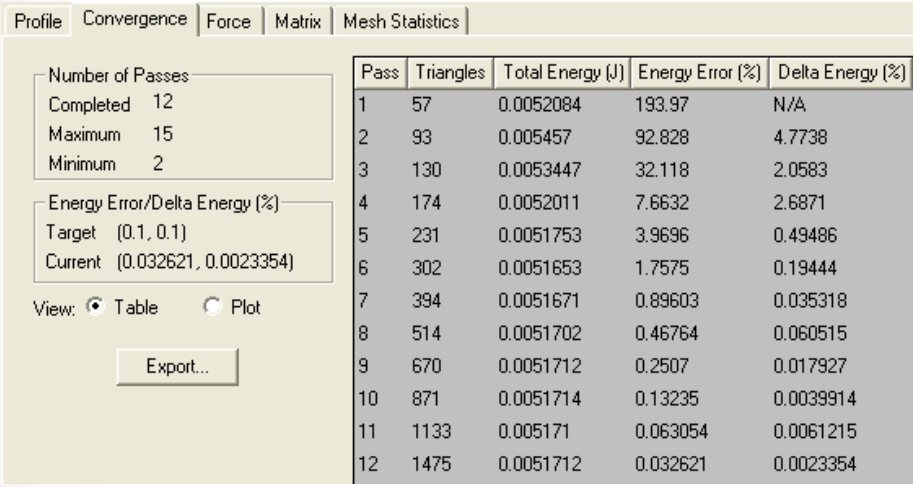




Analyze

- **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

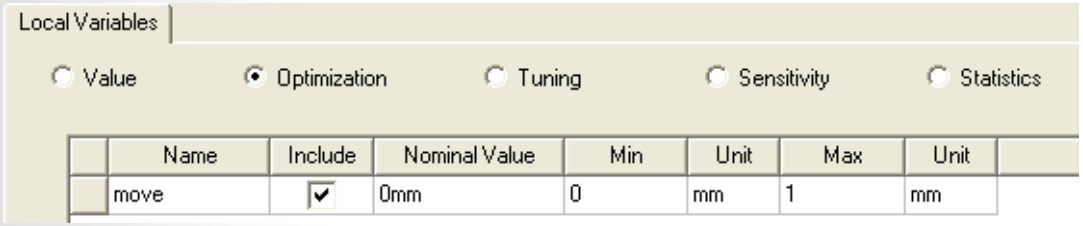




Pass	Triangles	Total Energy (J)	Energy Error (%)	Delta Energy (%)
1	57	0.0052084	193.97	N/A
2	93	0.005457	92.828	4.7738
3	130	0.0053447	32.118	2.0583
4	174	0.0052011	7.6632	2.6871
5	231	0.0051753	3.9696	0.49486
6	302	0.0051653	1.7575	0.19444
7	394	0.0051671	0.89603	0.035318
8	514	0.0051702	0.46764	0.060515
9	670	0.0051712	0.2507	0.017927
10	871	0.0051714	0.13235	0.0039914
11	1133	0.005171	0.063054	0.0061215
12	1475	0.0051712	0.032621	0.0023354

Optimetrics Setup

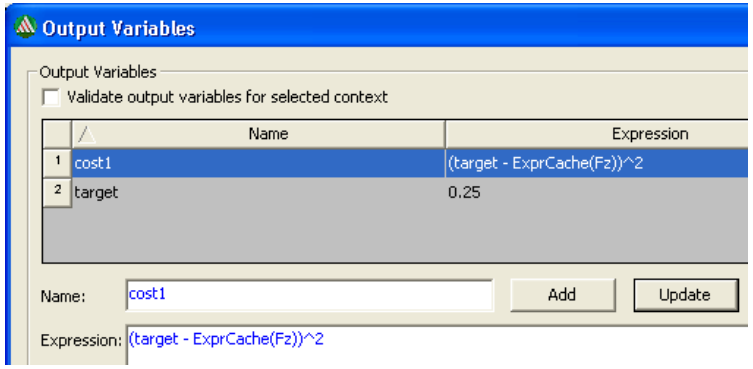
- **Optimetrics Setup**
  - It is possible to optimize position in order to obtain the specified force. For this optimization, the position will be varied to obtain a desired force of 0.25N.
- **Specify Parametric Variables**
  - Select the menu item ***Maxwell 2D → Design properties***
  - In Properties window,
    1. Optimization: ☑ **Checked**
    2. move:
       - Include: ☑ **Checked**
       - Min : **0 mm**
       - Max : **1 mm**
    3. Press **OK**



Note: Unless parameters are included in Optimization, they will not be available for Optimization Setup

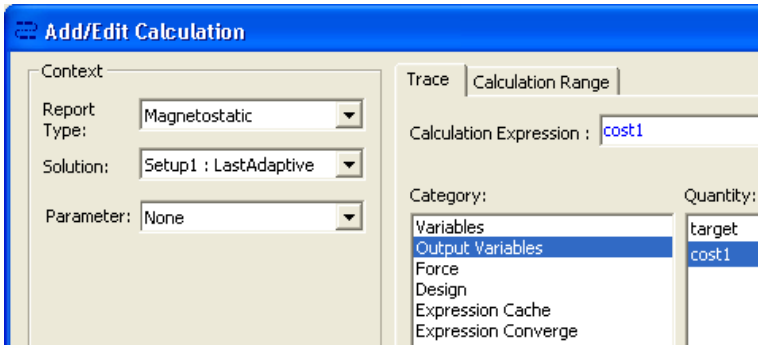
Optimetrics Setup (*Contd…*)

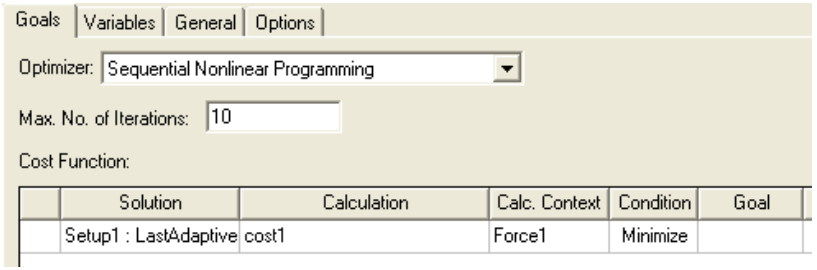
- **Setup Optmization**
  - Select the menu item ***Maxwell 2D → Optimetrics Analysis → Add Optimization***
  - In Setup Optimization window,
    1. Optimizer: **Sequential Nonlinear Programming**
    2. Max. No. of Iterations: **10**
    3. Select **Setup Calculations**
    4. In Add/Edit calculations window, select **Output Variables**
    5. In Output variables window,
       - Name: **target**
       - Expression: **0.25**
       - Select **Add**
       - Set name to **cost1**
       - Expression: **(target - ExprCache(Fz))^2**
       - Press **Add**
       - Press **Done**

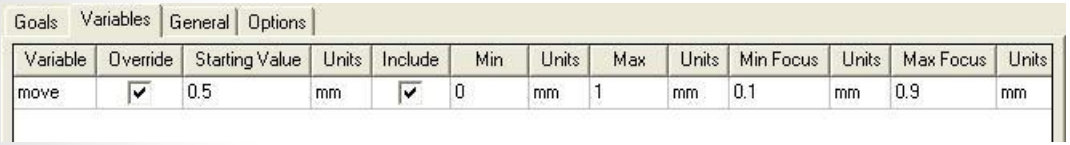


Optimetrics Setup (*Contd…*)

- **Setup Optmization *(Contd…)***
  6. In Add/Edit Calculations window,
     - Parameter : **Force1**
     - Category: **Output Variables**
     - Quantity: **cost1**
     - Select **Add Calculation** and **Done**
  7. Set Condition for **cost1** to **Minimize**
  8. Change the tab to **Variables**
  9. For the variable **move**
     - Starting value: **0.5mm**
     - Min: **0 mm**
     - Max: **1 mm**
     - Press **OK**





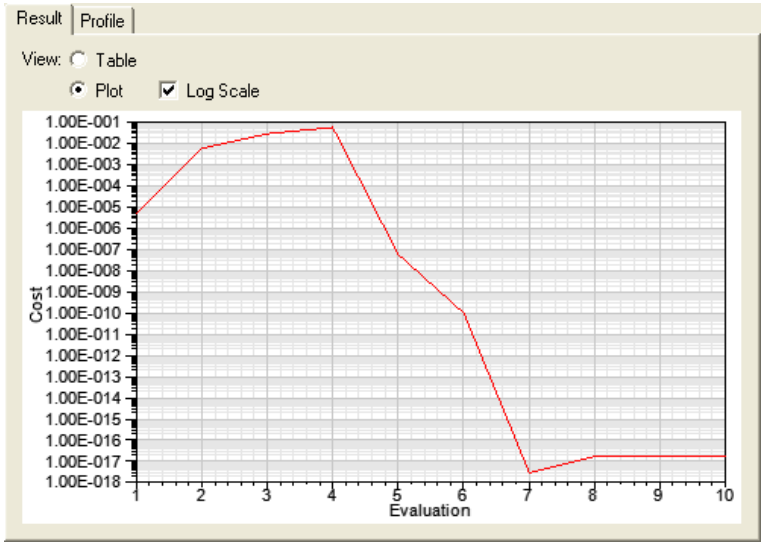


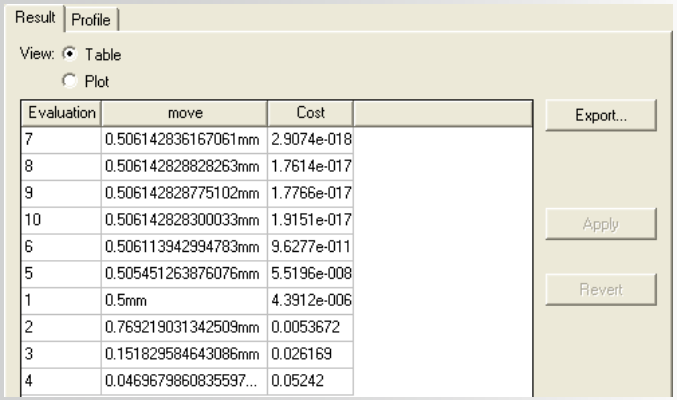
Note: Above Optimization Setup will vary move parameter in the range 0 to 1mm in order to minimize Cost1 which is difference between Target and Calculated value

Users can set min and max focus points on Variables tab if probable location of minima is know.

Run Optimization

- **Solve Optimization Analysis**
  - Expand the Project Manager tree to view **Optimetrics**
  - Right click on the tab **Optimization Setup1** and select **Analyze**
- **View Optimetrics Results**
  - Select the menu item ***Maxwell 2D → Optimetrics Analysis → Optimetrics Results***
  - In Post Analysis Display window,
    1. Log Scale: ☑ **Checked**
  - Change View to **Table** to see actual values
  - Minimum value comes at around **0.45mm**





Evaluation	move	Cost
7	0.506142836167061mm	2.9074e-018
8	0.506142828828263mm	1.7614e-017
9	0.506142828775102mm	1.7766e-017
10	0.506142828300033mm	1.9151e-017
6	0.506113942994783mm	9.6277e-011
5	0.505451263876076mm	5.5196e-008
1	0.5mm	4.3912e-006
2	0.769219031342509mm	0.0053672
3	0.151829584643086mm	0.026169
4	0.0469679860835597...	0.05242

Create Plot of Cost vs Move

- **Create Report**
  - Select menu item ***Maxwell 2D → Results → Create Magnetostatic Report → Rectangular Plot***
  - In Report window,
    1. Category: **Output Variables**
    2. Quantity: **cost1**
    3. Select **New Report**
- **Modify Plot Attributes**
  - Double click on **Y axis** of plot
  - In Properties window,
    1. **Scaling** tab
       - Axis Scaling: **Log**
       - Pres **OK**