Position Sensor-Simulation with ANSYS® Maxwell 3D

(Hands-On Notes)

Topics: Introduction into Maxwell for static magnetic field simulation

CADFEM

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1 Position Sensor Simulation

1.1 Introduction

The correct measurement of an angular position (or speed) is required in many different applications. One of the typical realization principle is based on the evaluation of the magnetic field quantities which are effected by moveable (rotating) permeable region nearby. Many of such applications are using a difference signal of 2 field sensors(e.g. Hall or MR elements) to measure the H-Field showing reluctance effects (for static methods) or eddy effects (for dynamic effects).

A well known application of such a principle using MR-elements is shown in figure 1. Here cylindrical permanent magnet works as a field source for the 2 sensor elements and the structured rotating wheel.

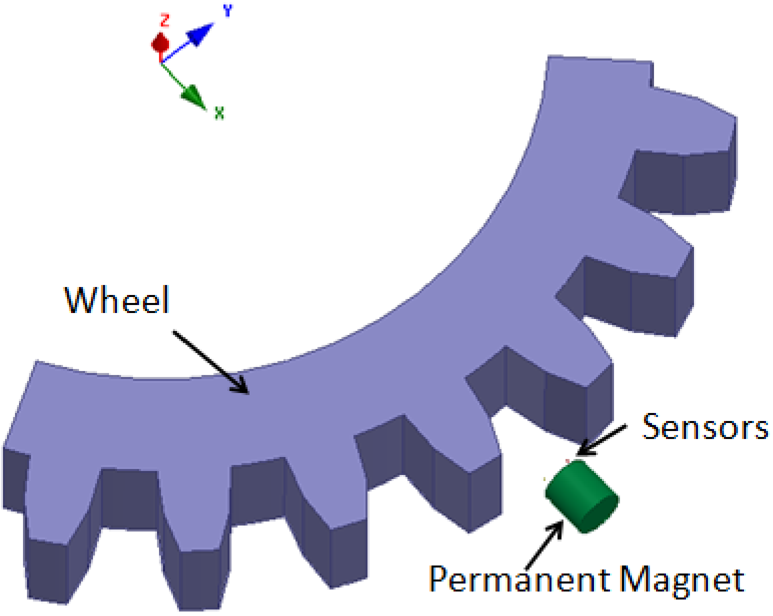


Figure 1

While the field source remains constant, the magnetic resistance depends on the angular position of the structured wheel.

Figure 2 gives a more detailed picture of the region of interest (sensor region). As the size of the sensors is significantly small compared to the wheel, the simulation needs to evaluate the field distribution with care.

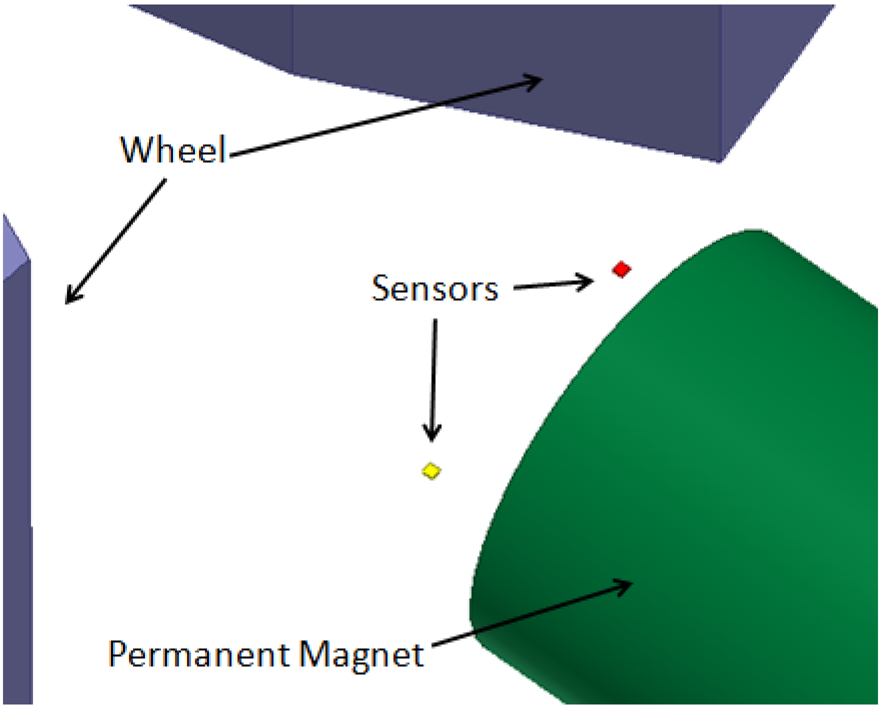


Figure 2

The goal of the simulation is to determine the field quantities with respect to the angular position of the wheel. In some further optimization runs – the difference signal should be optimized, while the magnet size should be minimized.

1.2 First Steps (initial Settings of Workbench)

- Open ANSYS Workbench
- Set the Language to English: *Tools > Options… > Regional and Language Options > Language > English*
- Close ANSYS Workbench, that the language changes become active
- Open ANSYS Workbench again.

1.3 Setting up Sensor Simulation

- Insert a new Maxwell3D Simulation (from analysis systems inside the project page)
- Open Maxwell3D (double-click onto the analysis system)

The figure shows the GUI of ANSYS Maxwell:

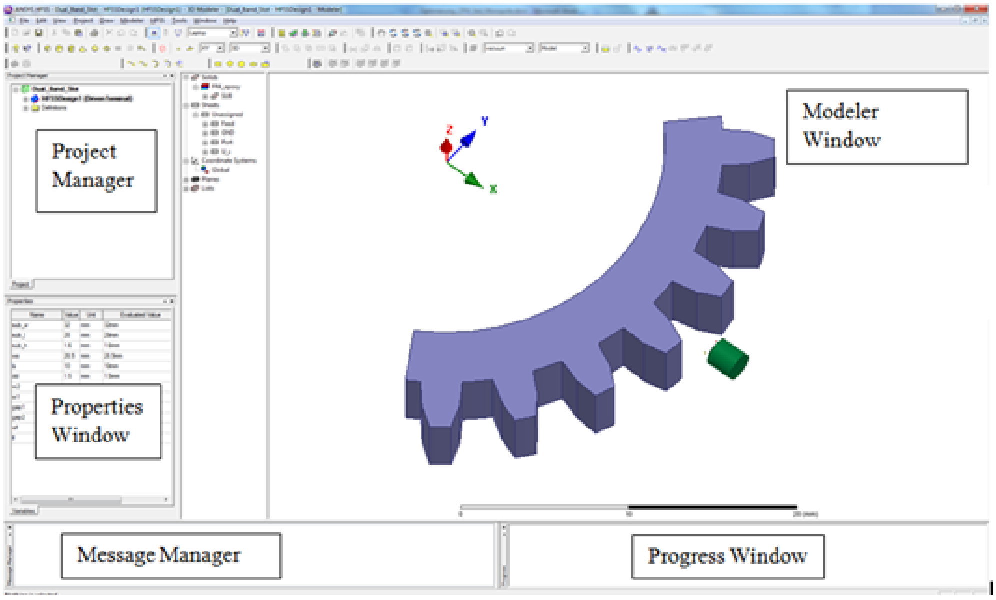


Figure 3

Modeling Setup

- Import the Geometrie (Parasolid): Modeler > Import… > SENSOR_GEOM.x_t

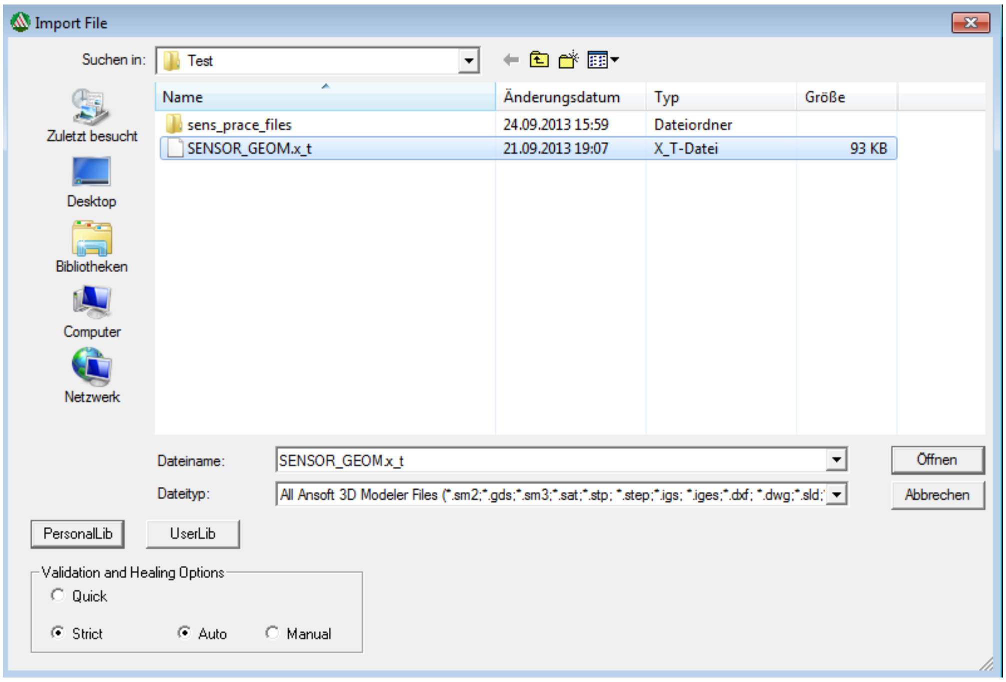


Figure 4

- Save the Workbench Project: File > Save As… > SENSOR_GEOM.x_t.wbpj
- Open the Maxwell3D component system

Assign Material Properties to all Solid Parts:

- Point onto the Magnet (inside Solid Tree or within graphics window)
- Use RMB to choose Assign Material

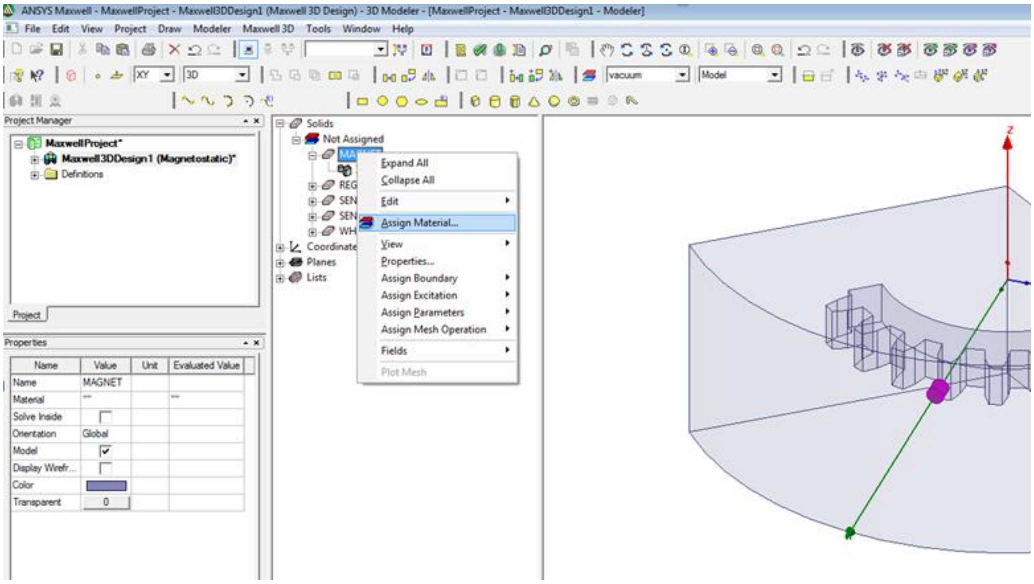
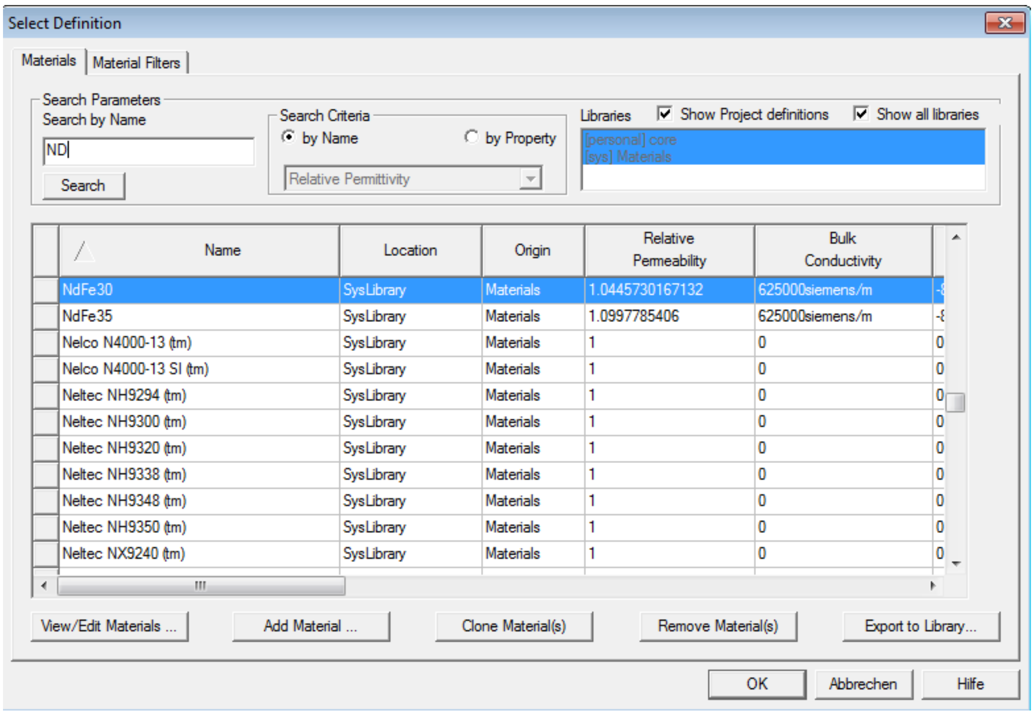


Figure 5

- Insert "NdFE" into the material name box to search for existing data sets



- Accept the material with OK

You may check the content of the material data (from Library) – as well as adjust settings with the View/Edit function. Here you can see that the magnetization direction is oriented as global X direction. This setting is correct for our analysis here.

Proceed similar for the other solids, to point vacuum to the sensors (the are non magnetic regions) , as well as the region. Choose “Iron” from the library to point onto the wheel. For the first analysis the linear description of iron is suitable here.

The graphics properties can also be adjusted for each solid. You may use the Properties Window (left side under the tree) to adjust colors and transparency. Moreover also the use of the solid within the simulation can by specified (Model or Non-Model).

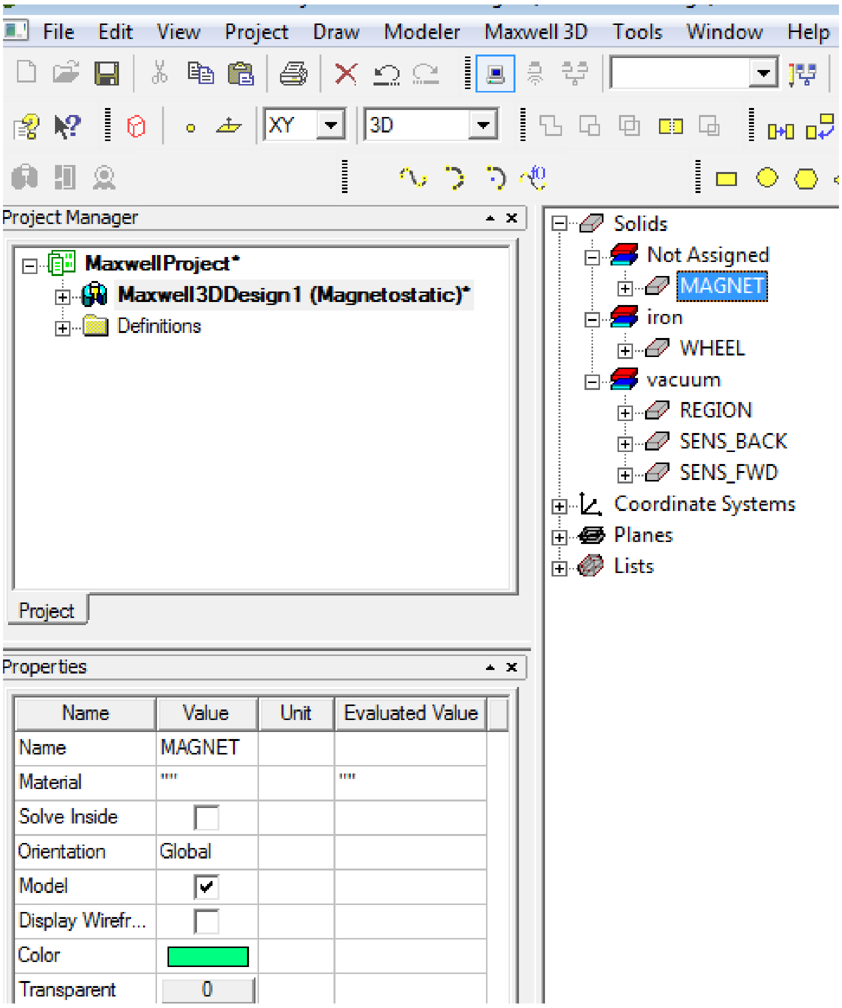


Figure 6

As the next step, the boundary condition should be set. Thus its helpful to rotate the model. This can be done with the middle mouse button, while the scroll-wheel helps for zooming in and out.

Assume the field at the end regions of the sector of the wheel are not effected by the magnet – a flux parallel boundary condition (natural) is sufficient for the basic setup.

The definition of initial mesh parameters help to improve the performance and accuracy. For this step a sizing for the sensor region is required.

- Select the Sensor Solids
- Use RMB to choose Apply Mesh Operation > Inside Selection > Length based

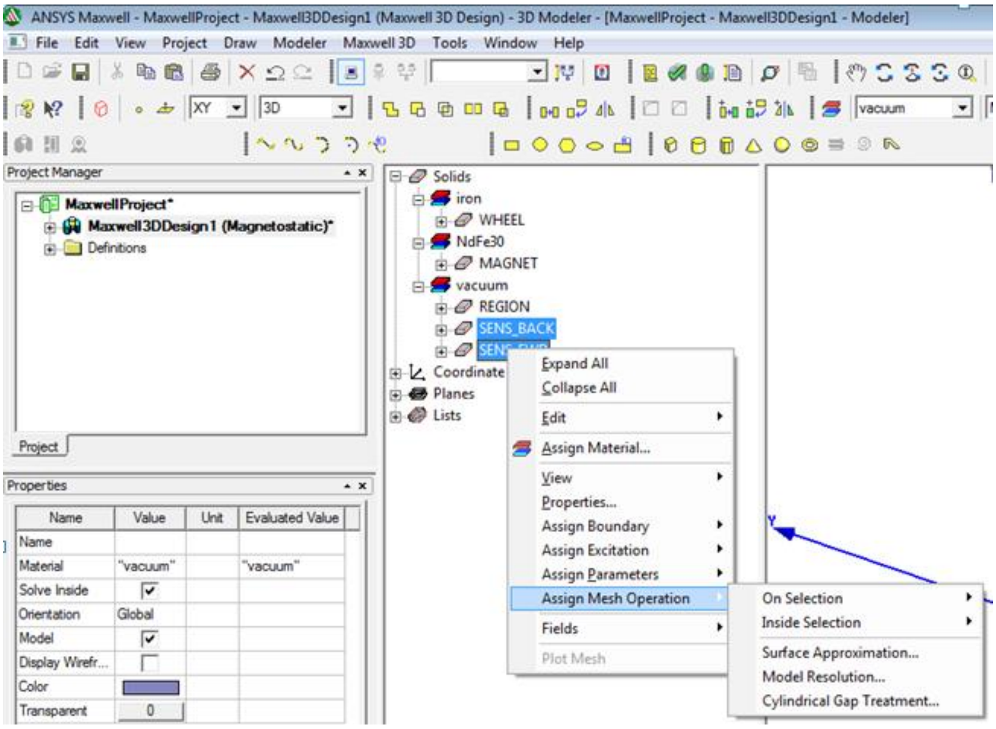


Figure 7

- Specify 0.02 mm

Proceed similar to define 1mm for the magnet and 3 mm for the wheel.

As the basic setup is nearly finished – the analysis setup can be implemented:

- RMB in Analysis > Add Solution Setup

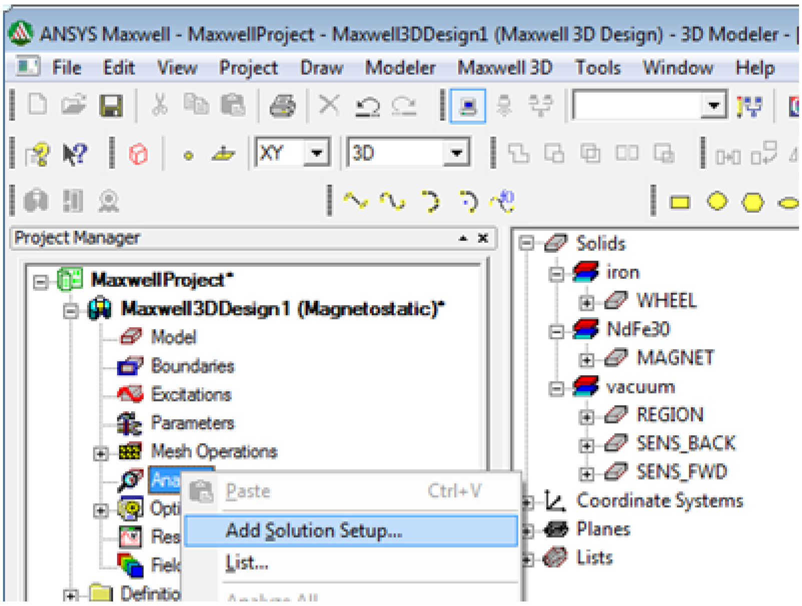


Figure 8

The original setup shows 10 adaptive iterations to fulfil the energy criteria (global)

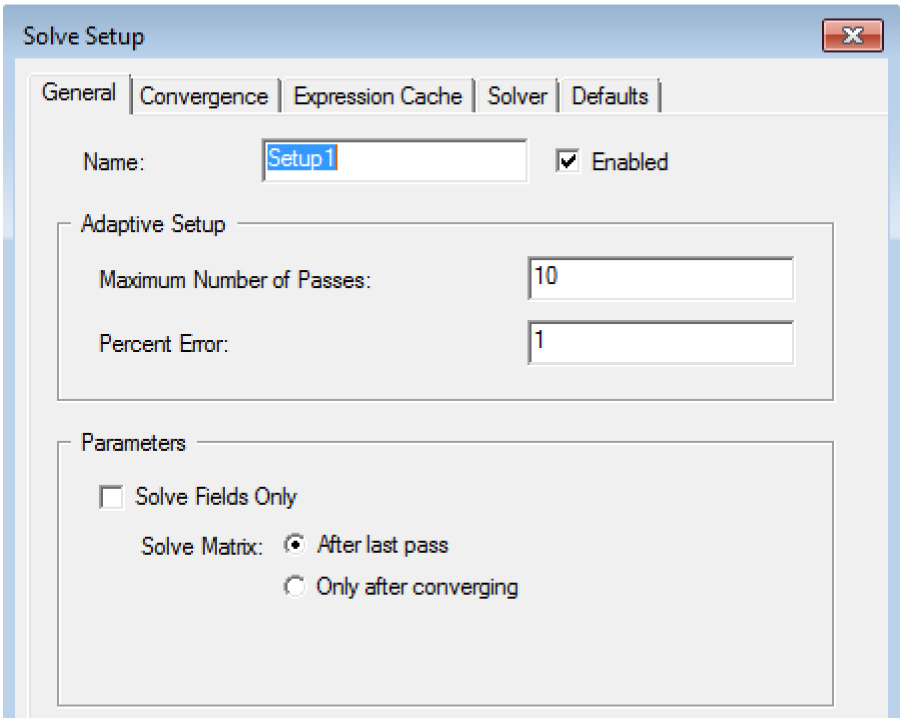


Figure 9

The validation checking can be used to validate of all requirements for the analysis are fulfilled. Use the appropriate function from the main menu.

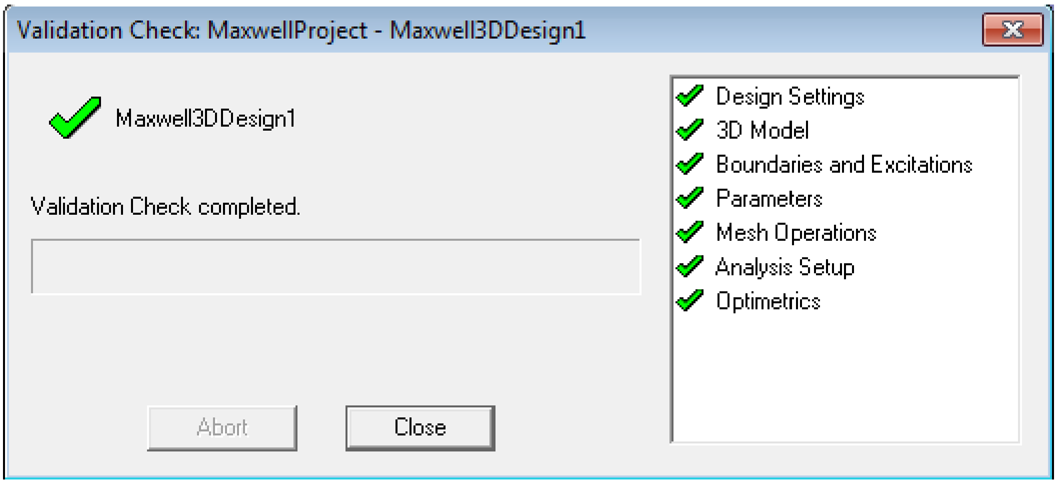


Figure 10

Next the analysis can be started.

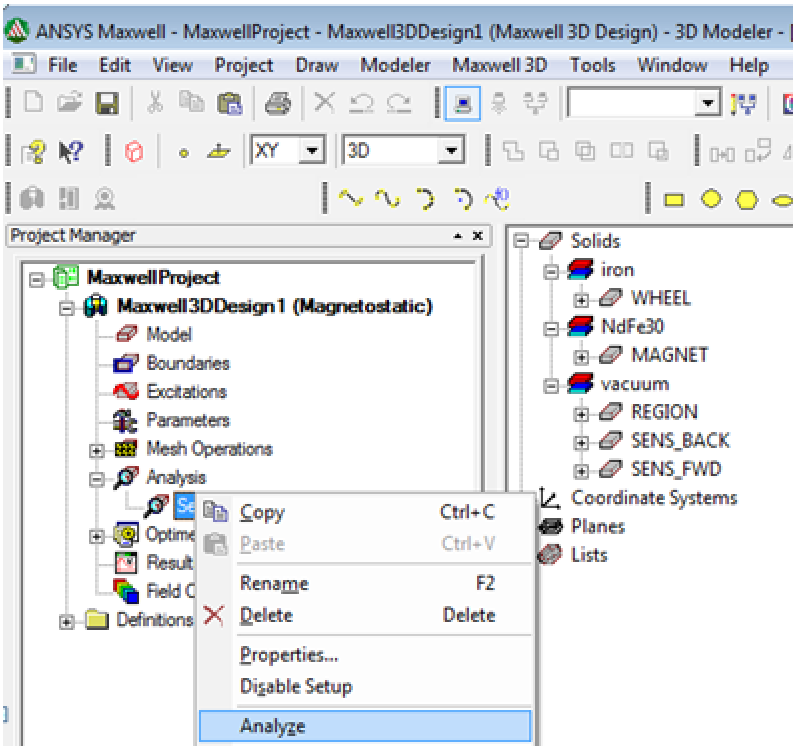


Figure 11

The simulation progress can be seen on the main screen – showing also the adaptive iterations.

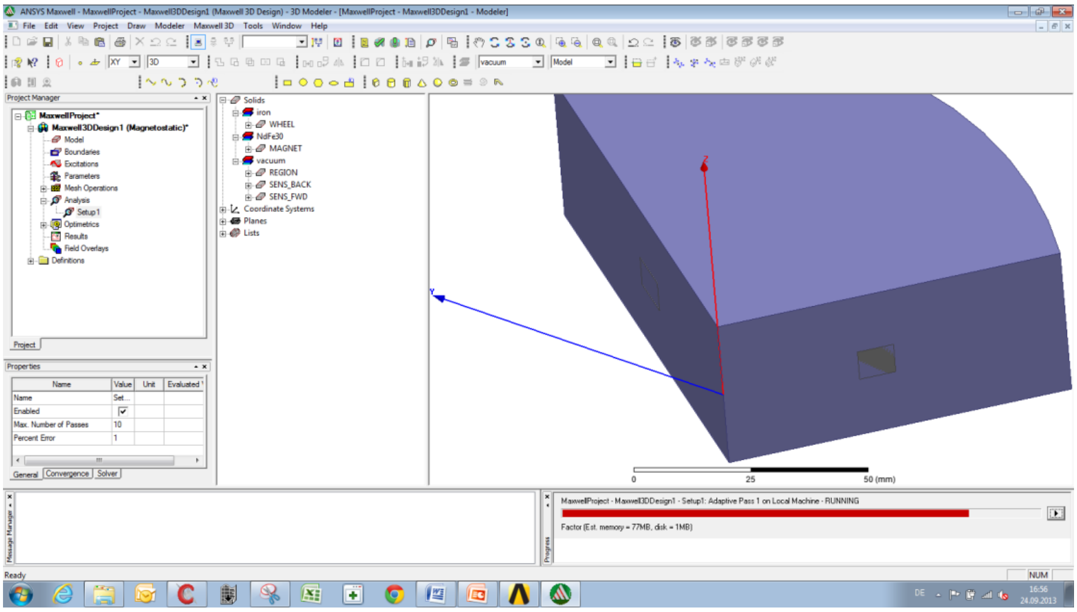


Figure 12

The convergence can be check with:

- RMB Analysis Setup1> Convergence

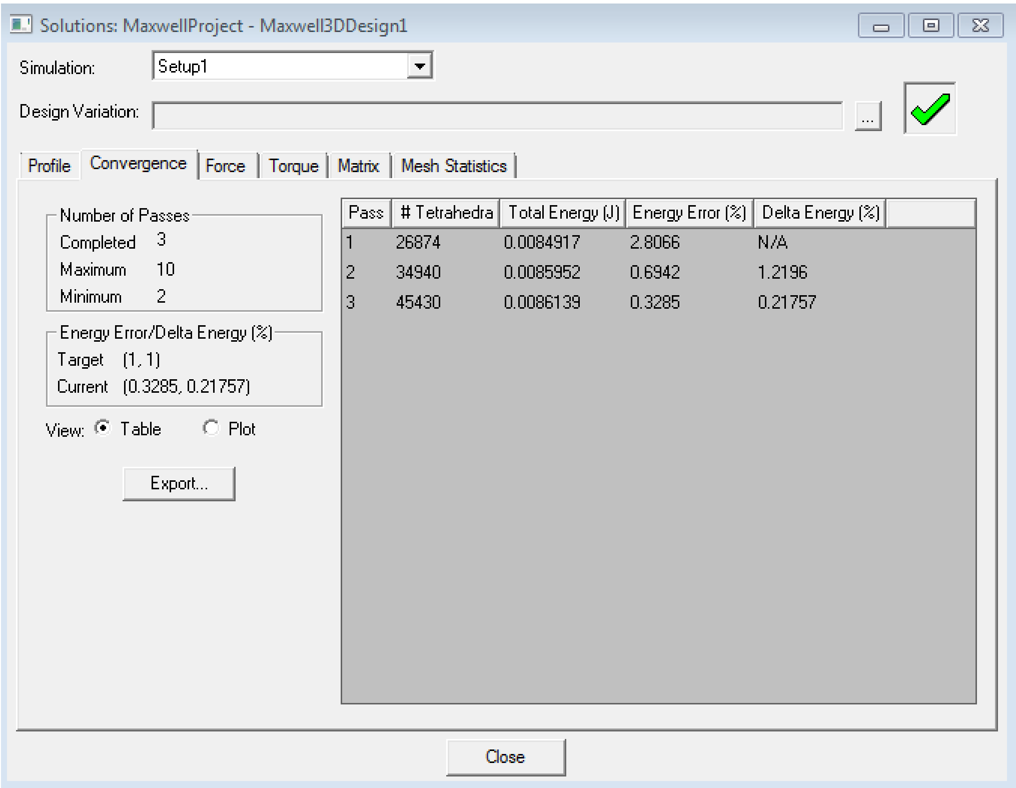


Figure 13

To proceed with some further steps, it may be helpful to hide the field region. This can be done with the “eye” filters in the main menu.

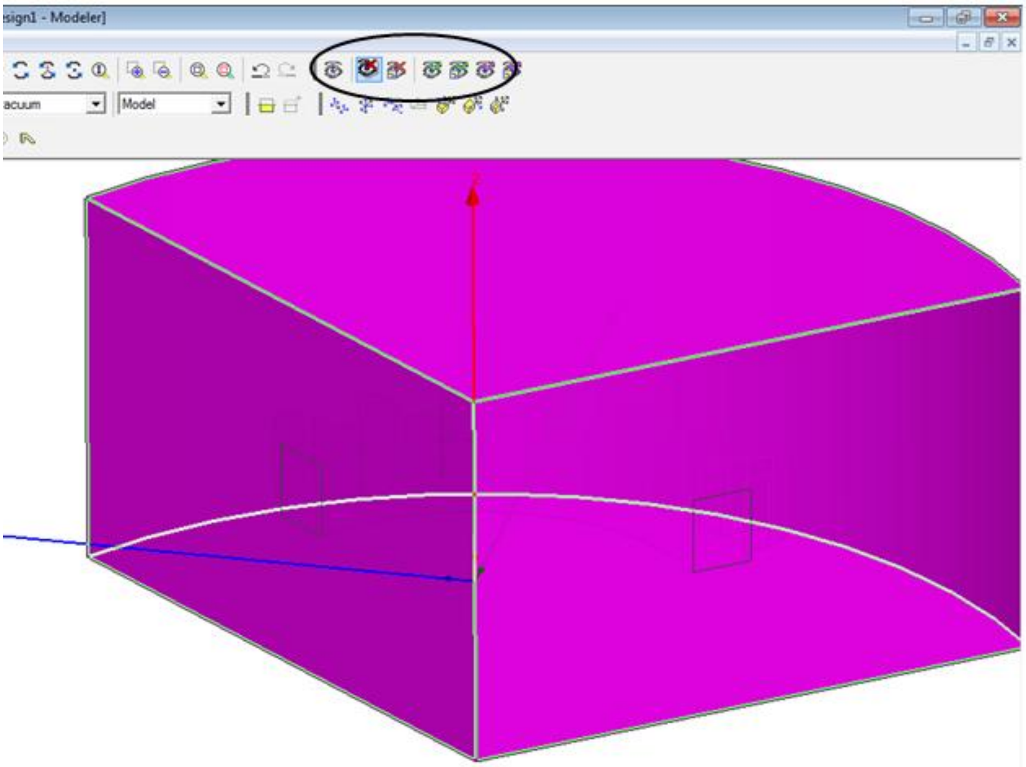


Figure 14

Resulting to the picture of figure 15.

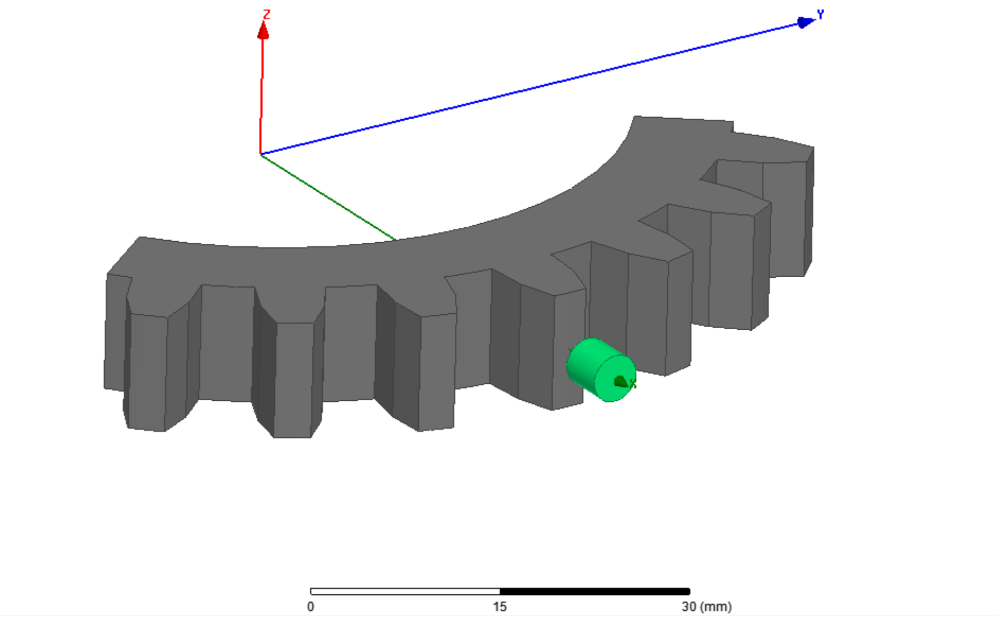


Figure 15

Insert a field-plot to display the magnetic field of the wheel.

- Select the solid body of the wheel
- Use RMB to choose Fields > H> Mag_H

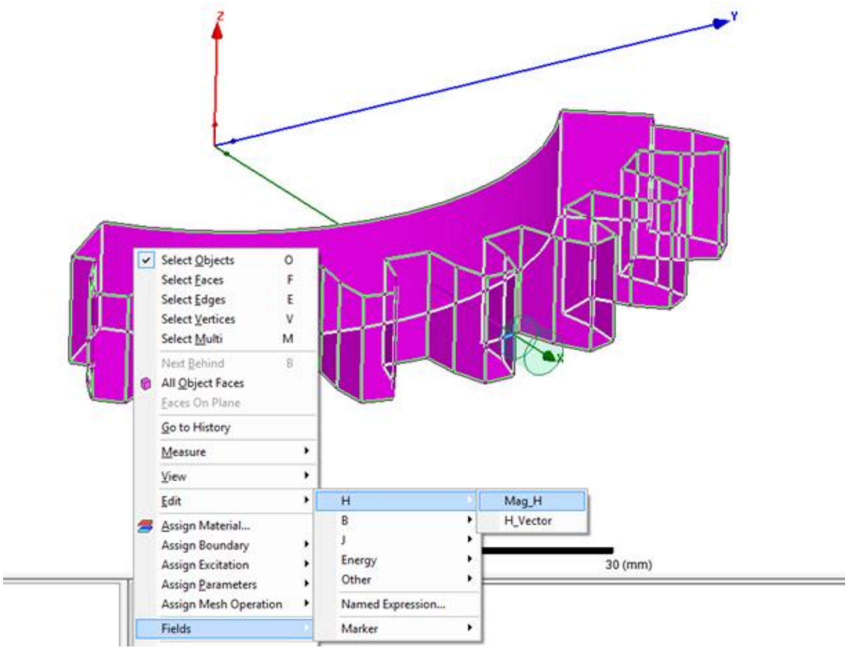


Figure 16

- Check the Box “on surface only” to create a contour plot

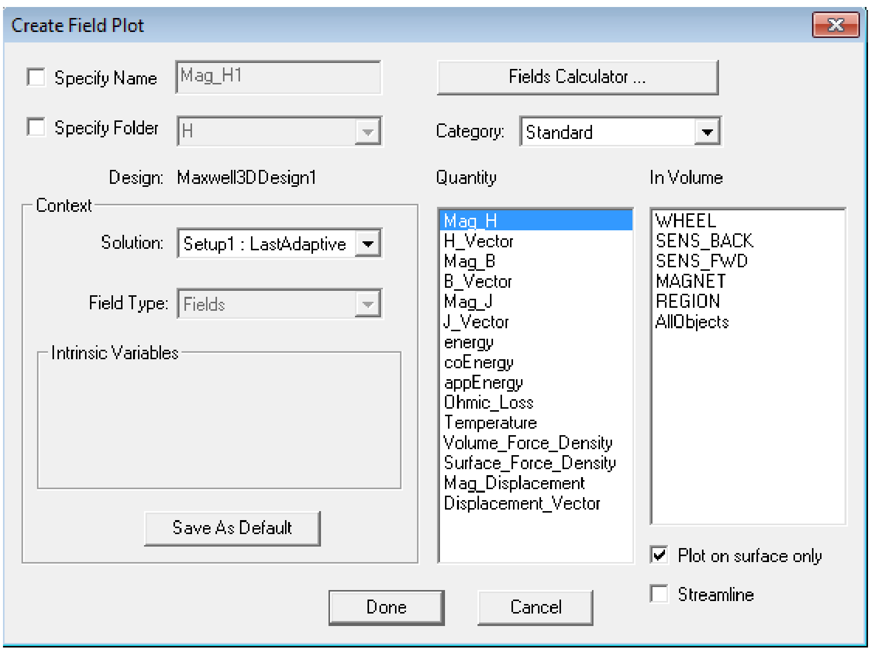


Figure 17

The resulting field plot should look like figure 18. The field is concentrated to the region near to the magnet and will be symmetric, as the initial position with respect to the structure of the wheel is also symmetric.

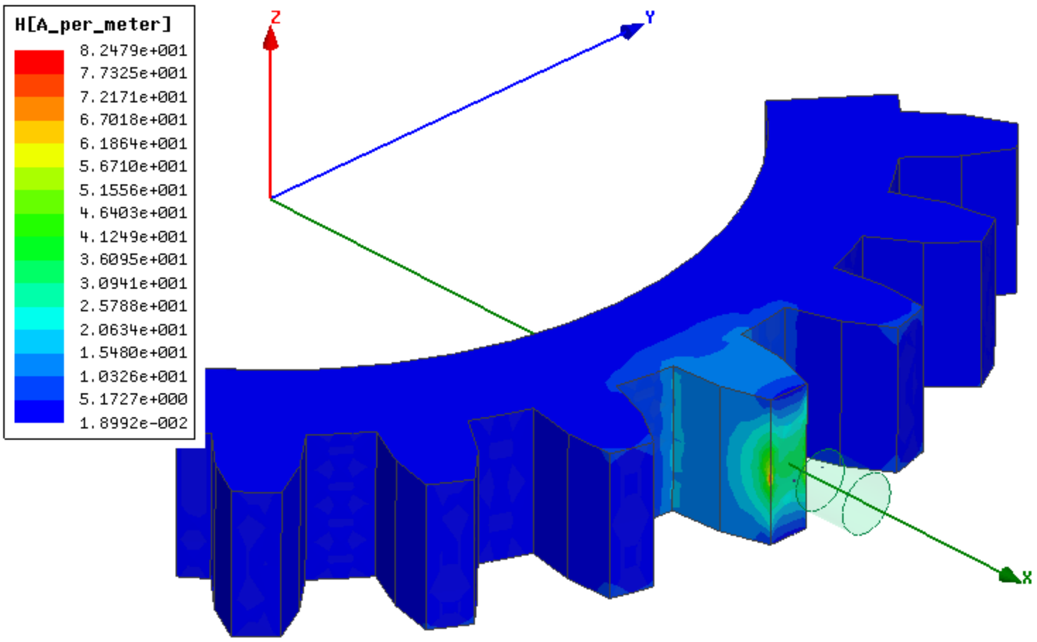


Figure 18

1.4 Sensor Parameter Setup (Calculator)

As the sensor signal is derived from the magnetic field in the region of the sensor domain, the field calculator of Maxwell will be used to determine this data.

- Select Field Overlays (in tree) > RMB Calculator

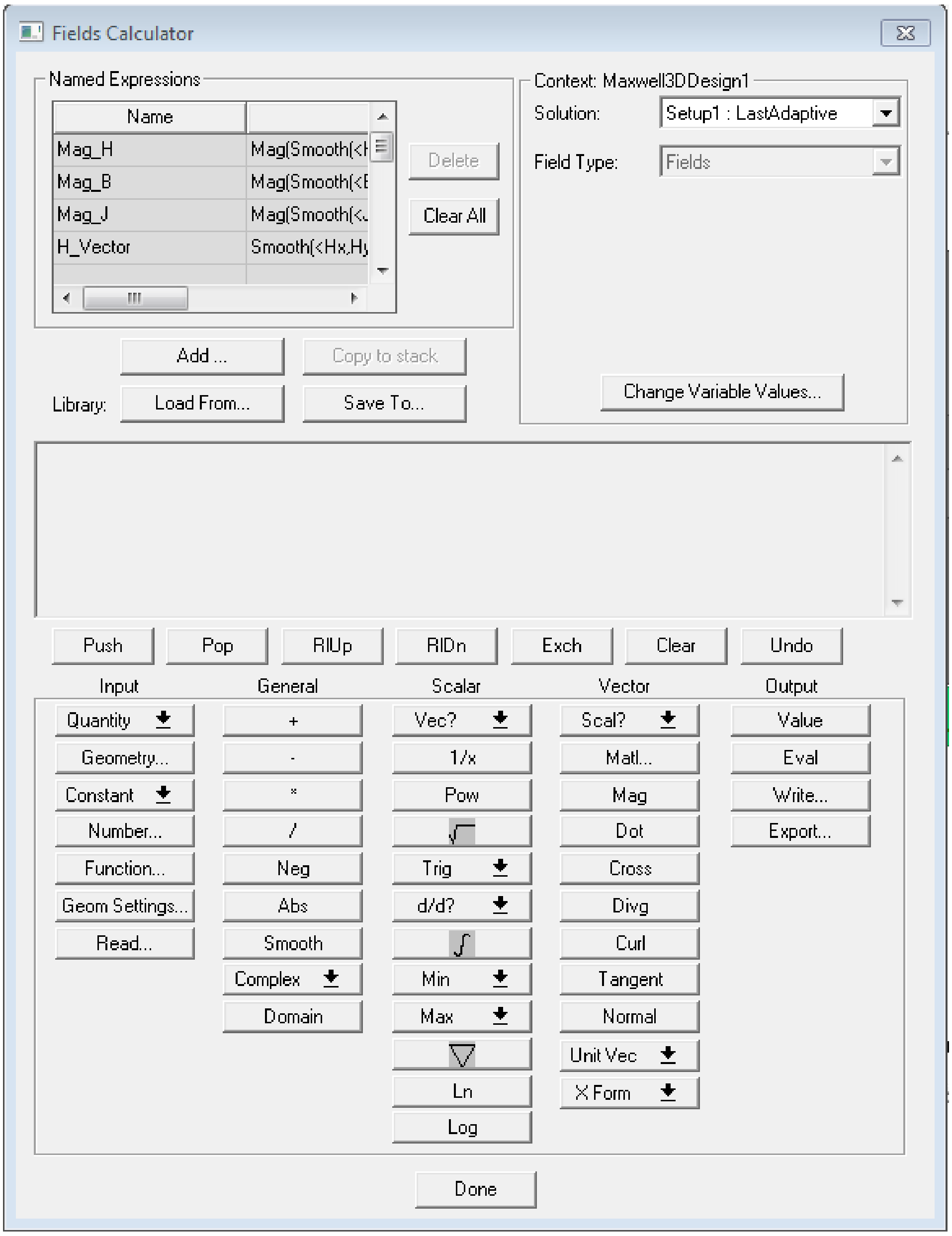


Figure 19

The equation in figure 20 shows the relation that should be evaluated with the field calculator for both sensors:

$$\alpha = \tan^{-1}\left(\frac{\int H_y dv / V}{\int H_x dv / V}\right)$$

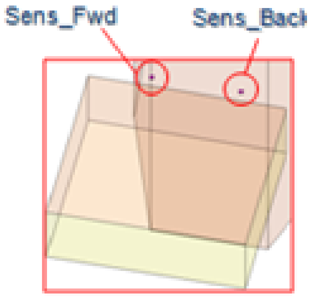


Figure 20

For the Forward Sensor (FWD)

- Qty ▪ H ▪ Scalar ▪ Y
- Geom ▪ Sens_Fwd ▪ Integ
- Qty ▪ H ▪ Scalar ▪ X
- Geom ▪ Sens_Fwd ▪ Integ
- /
- Trig ▪ Atan
- Constant ▪ PI ▪ /
- Number ▪ 180.0 ▪ *
- [Add] → Ang_Fwd

And also for the Backward Sensor (Back)

- Qty ▪ H ▪ Scalar ▪ Y
- Geom ▪ Sens_Back ▪ Integ
- Qty ▪ H ▪ Scalar ▪ X
- Geom ▪ Sens_Back ▪ Integ
- /
- Trig ▪ Atan
- Constant ▪ PI ▪ /
- Number ▪ 180.0 ▪ *
- [Add] → Ang_Back

Finish with DONE.

The evaluated quantities can be displayed with:

- Results RMB> create field report > Data table
- Choose from the calculator expression ANG_BACK and ANG_FWD
- New report

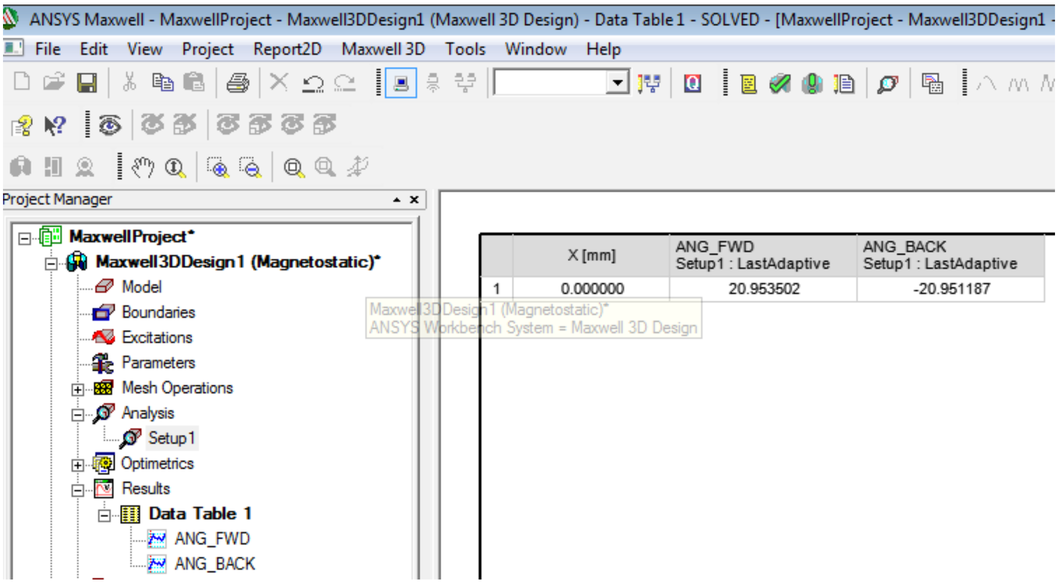


Figure 21

Insert these variables as convergence criteria:

- RMB Analysis Setup 1 > Properties > Expression Cache > Add
- ADD the ANG_BACK and ANG_FWD
- Done
- Adjust the convergence to 0.05 for each parameter

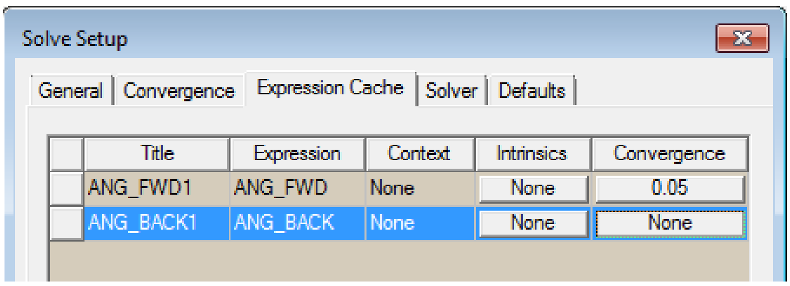


Figure 22

The next analysis run will also consider this definition.

1.5 Insert Parametric Rotation of the Wheel

As the sensor detects the field quantities as a function of the angular position of the wheel, a rotation of the geometry is inserted:

- Select the Wheel and Region !
- RMB > Edit > Arrange > Rotate > type angle into the data field to rotate about z

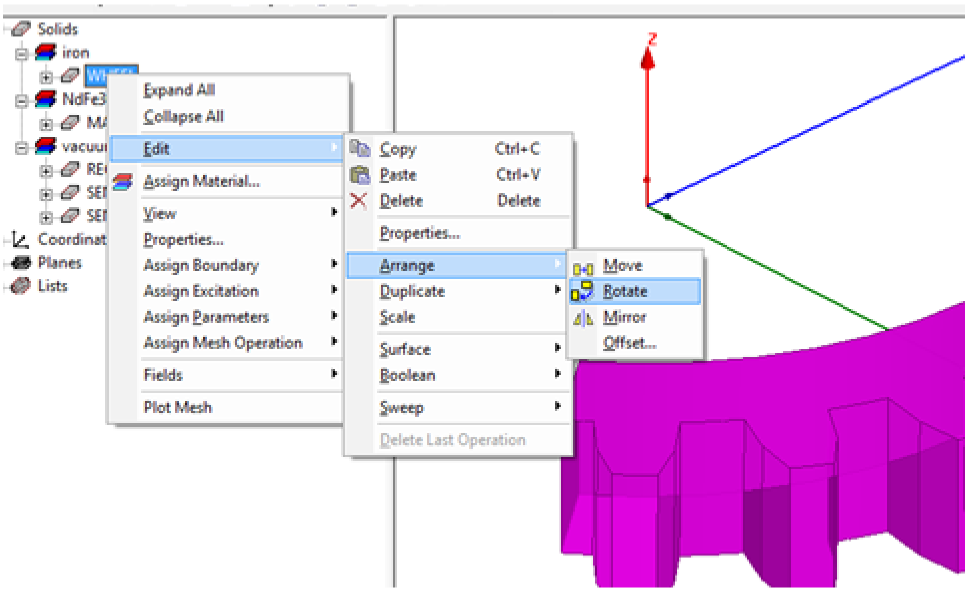


Figure 23

The program will ask for the value of the new defined parameter “angle”:

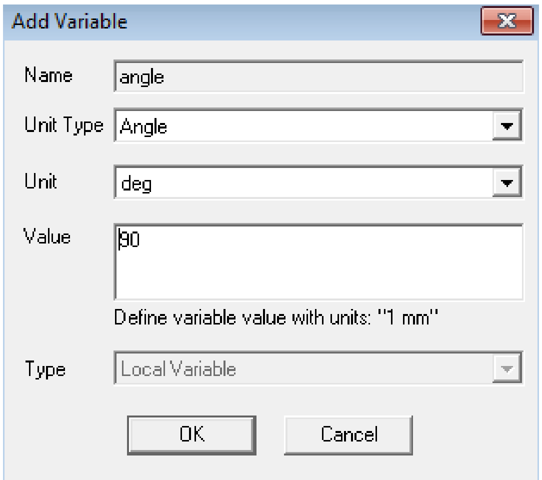


Figure 24

Type an initial value of 0 into the field and finish with ok. The parameter could be found and adjusted in details window (properties) of the Maxwell3DDesign.
This can also be used to check the operation with different values.

1.6 Workbench Parametric Run

To evaluate the function of the field values (for the sensor) relating to the position the Workbench Parameter Run can be used (in combination with other physics or the optimization tool OptiSlang)

- Choose Optimetrics > DefaultDesignXplorerSetup
- RMB properties > check include to the variable angle
- Choose Calculation Tab > Add Expression Cache for Ang_FWD and Ang_BWD
- Done and OK

Save the Simulation Setup within Maxwell (Crtl+S). This will link the Maxwell parameters into WB.

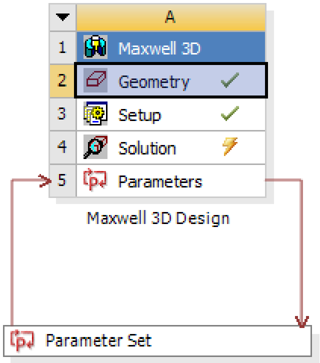


Figure 25

Now the parameter sets can be defined and the parametrized analysis could be started:

- Double-Klick onto the Parameter Set
- Type a new value into the empty field under the existing angle (line2 = current design)
- Proceed to define values from -7.5 to 7.5
- Use Update Project or Update All Design Points to start a local run of the simulation

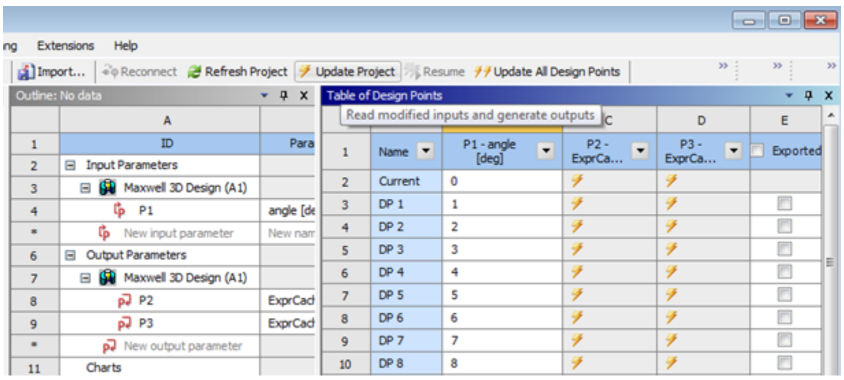
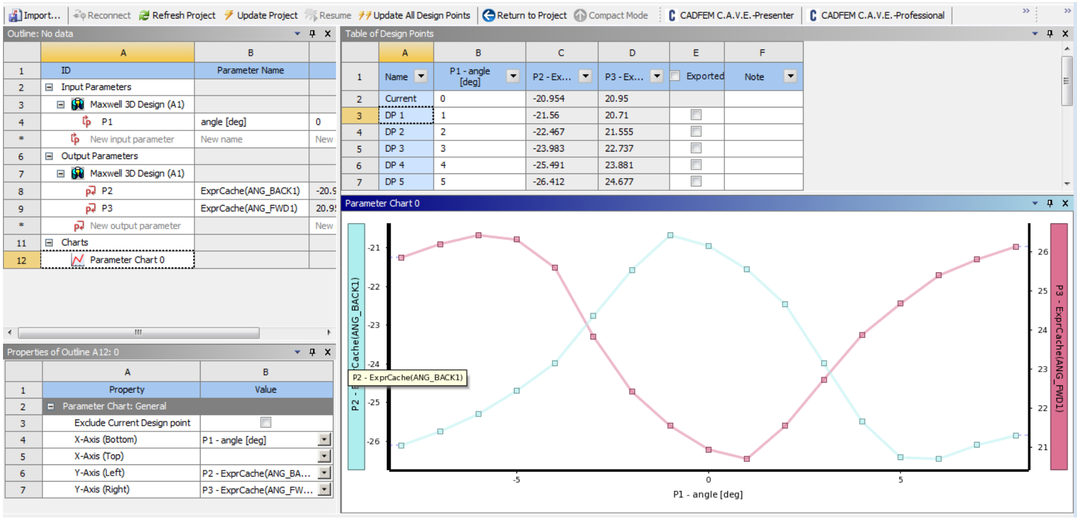


Figure 26

The evaluated curves can be shown also inside the parameter manager with inserted charts:

- Insert Charts
- Choose Angle for the x axis definition
- Choose Ang_Back for y axis 1 and Ang_Fwd for y axis 2



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