MAG2W User's Guide

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MAG2W is a Windows program for designing coils to produce 2D transverse magnetic fields. The program uses fully-keystoned annular conductors or rectangular conductors. The annular conductor calculations can include the effects of circular, infinite permeability iron. The program displays the coil configuration graphically and shows the location of the peak field. It also shows the net force on each of the coil blocks. The normal and skew multipoles are listed. It can optionally display the field components on the midplane, the force distribution inside the coils, a grid of the magnetic field inside the aperture, magnetic lines of force, or the Fourier components around a reference circle. It also contains a built-in optimizer.

1. Starting the program

The program can be started from a DOS (command) window using the command

C:> mag2w

or

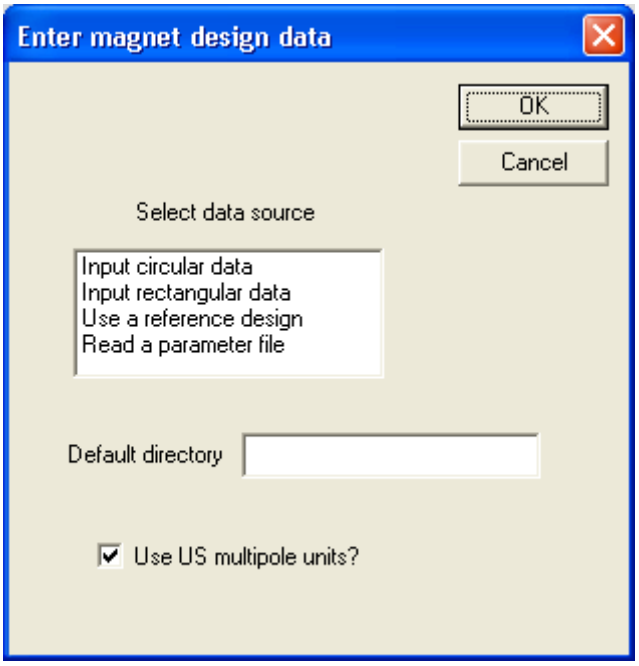
C:> mag2w file.prm

where *file.prm* is the name of an existing parameter file.

The program can also be started by clicking on its Windows icon.

2. Opening screens

The figure shows the opening screen when the program is started without specifying a pre-existing parameter file.

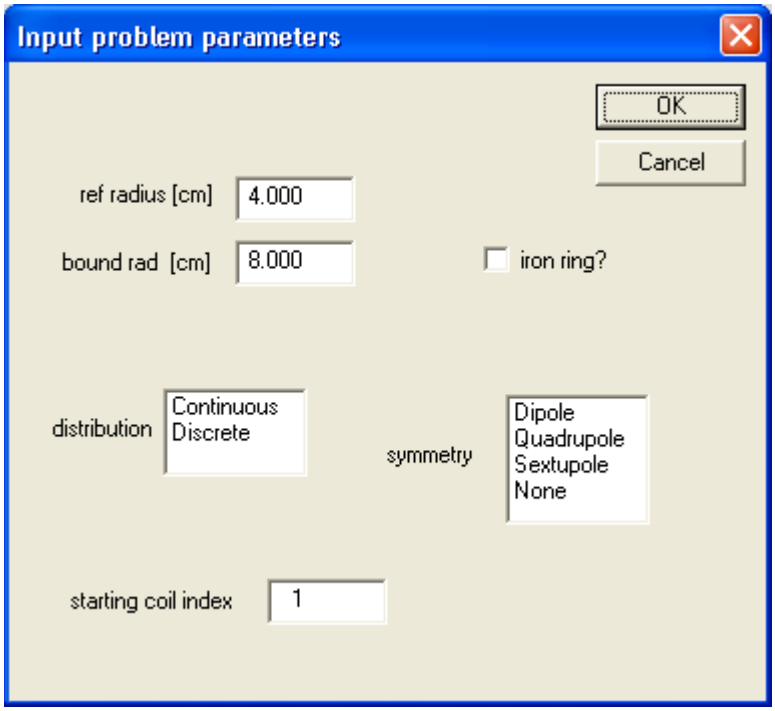


The user has four choices to enter the magnet design data. The first two choices allow inputting data for circular or rectangular coils by hand. The third choice brings up a list of built-in reference designs. The last choice is to read in a parameter file that had been previously saved or created offline.

The directory for reading and writing files may be set here. The check box determines whether the US definition of the multipole orders is used (e.g. B_0 is the normal dipole multipole in US units).

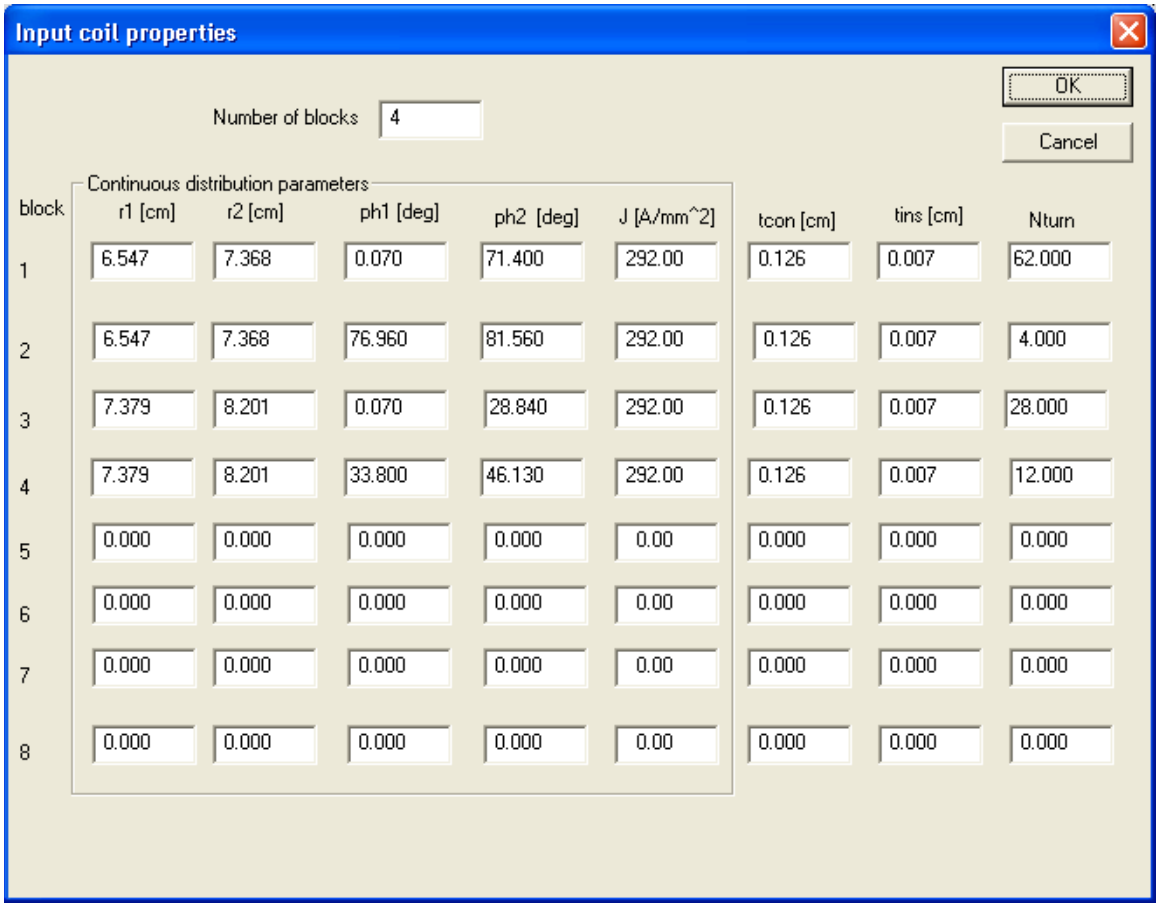
2.1 Entering circular data

If the user chooses to input circular data it brings up the window



The reference radius is used for calculating the multipoles. The boundary radius defines the outer edge of the field grids. It is also the inner radius of the iron if iron is present. The check box on the right determines whether iron is present. The distribution of the current in the coils can either be continuous or in discrete turns. The symmetry parameter causes duplication of coils defined in the minimum azimuthal sector (e.g. 0-90° for a dipole). The starting index for the eight coil blocks that will be shown on the following dialog may be set here. This can also be used to increase the number of blocks in an existing design.

The second input window specifies the actual coil parameters.



Input coil properties

OK

Cancel

Number of blocks 4

Continuous distribution parameters

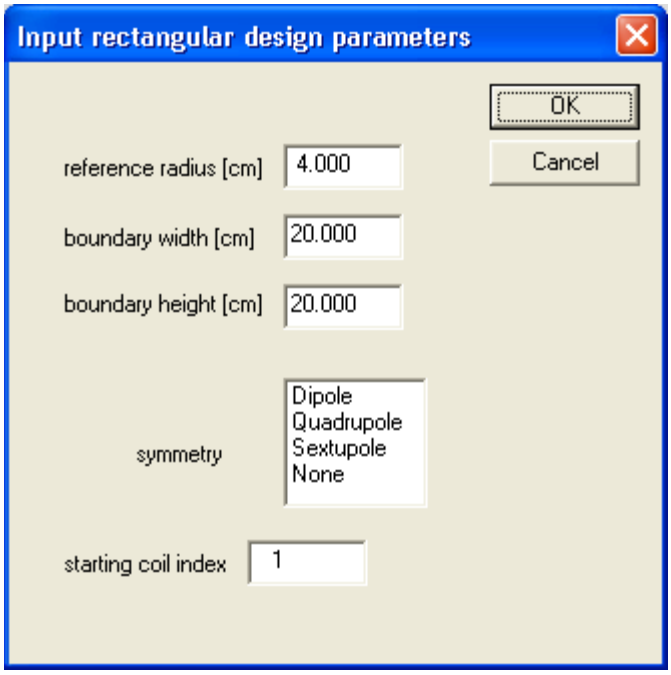
block	r1 [cm]	r2 [cm]	ph1 [deg]	ph2 [deg]	J [A/mm^2]	tcon [cm]	tins [cm]	Nturn
1	6.547	7.368	0.070	71.400	292.00	0.126	0.007	62.000
2	6.547	7.368	76.960	81.560	292.00	0.126	0.007	4.000
3	7.379	8.201	0.070	28.840	292.00	0.126	0.007	28.000
4	7.379	8.201	33.800	46.130	292.00	0.126	0.007	12.000
5	0.000	0.000	0.000	0.000	0.00	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.00	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.00	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.00	0.000	0.000	0.000

The number of defined coil blocks is given at the top. The user can specify the properties of up to 8 coils using this window. (Up to 16 coils can be defined offline by creating a suitable parameter file.) The first five columns define the quantities needed for continuous current distributions. These are the inner and outer radii, the starting and ending azimuthal angles, and the current density for an annular coil. The last three columns are used for discrete current distributions. These are the thickness of the conductor, the thickness of the insulation, and the number of turns in a coil block.

In discrete mode if all the azimuthal parameters {*ph1*, *ph2*, *tcon*, *tins*, *Nturn*} are given the angle *ph2* may be overwritten if the parameters are not self-consistent. A special tag -999 may be used to specify that a given azimuthal quantity is to be calculated from the other four. Another special tag -990 may be used for the start angle *ph1*of a block to specify that it equal the end angle *ph2* of the previous block.

2.2 Entering rectangular data

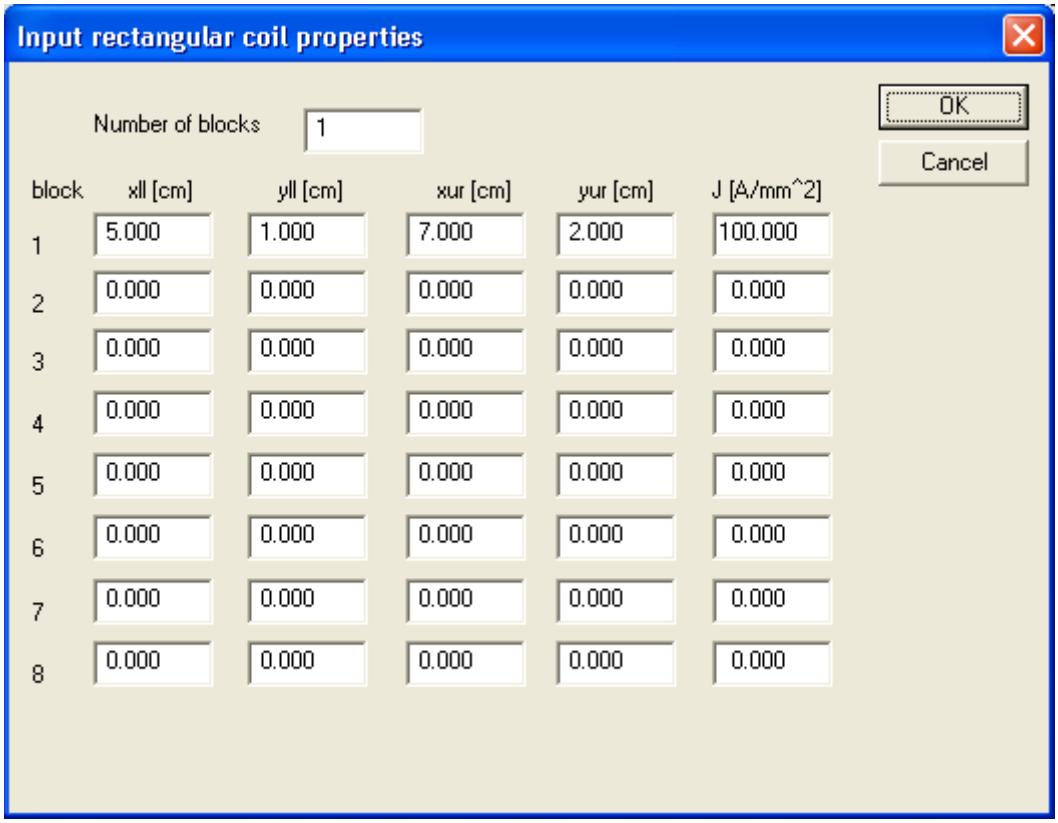
If the user chooses to input rectangular data it brings up the window



The reference radius is used for calculating the multipoles. The boundary height and width defines the outer edge of the field grids. The symmetry parameter causes duplication of coils defined in the minimum azimuthal sector (e.g. 0-90° for a dipole).

The starting index for the eight coil blocks that will be shown on the following dialog may be set here. This can also be used to increase the number of blocks in an existing design.

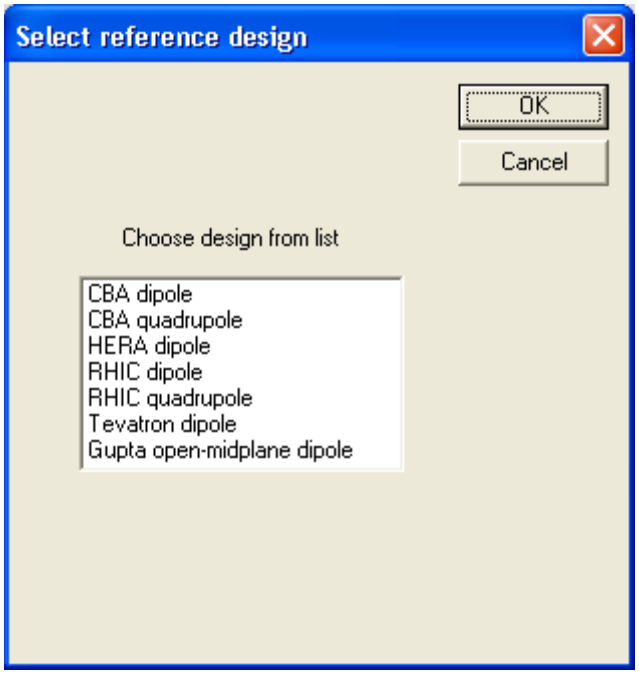
The second input window specifies the actual coil parameters.



The number of defined coil blocks is given at the top. The user can specify the properties of up to 8 coils using this window. (Up to 16 coils can be defined offline by creating a suitable parameter file.) The first two columns give the x and y coordinates of the lower-left corner of the conductor block. The next two columns give the x and y coordinates of the upper-right corner of the conductor block. The last column gives the engineering current density in the block.

2.3 Entering a reference design

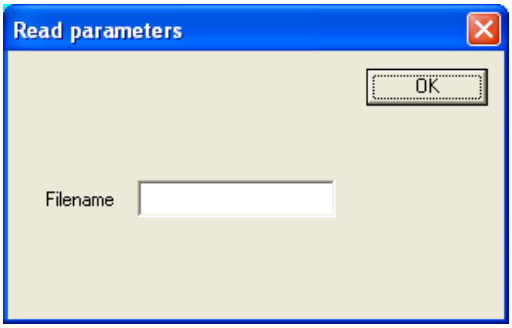
If the user chooses to enter a reference design it brings up the window



The user should click on an item in the list.

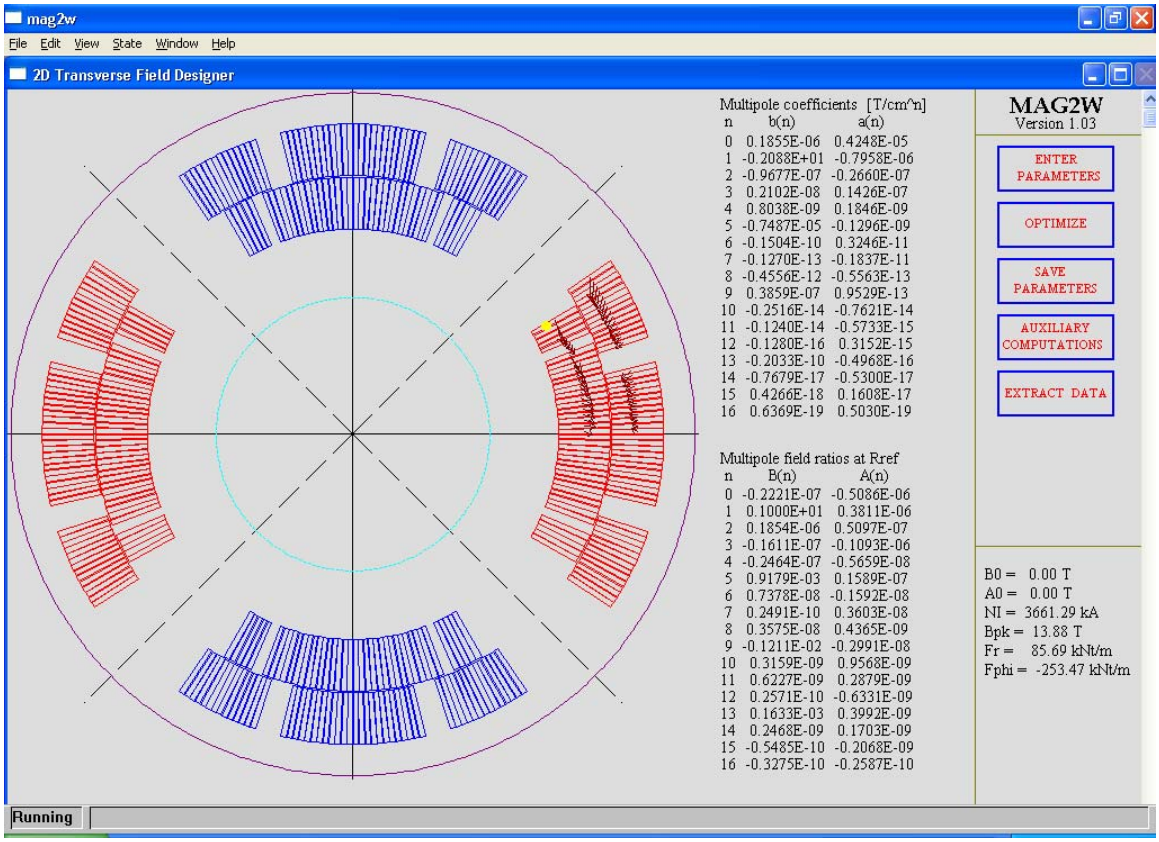
2.4 Entering a saved design

If the user chooses to enter a saved design it brings up the window



3. Results screen

After a design has been entered the program displays a screen similar to the following.



The large clear area on the left is used to graphically display the coil geometry, the peak field location, and the net force on each coil block. The multipole information is listed to the right of the coil display. The buttons on the right may be clicked to execute additional commands. The area on the lower right is used to display numerical values for some parameters.

In the graph on the left coils with positive current are shown in red, while coils with negative current are shown in blue. The purple circle is the boundary, which can also indicate the edge of an iron region with infinite permeability. The inner cyan circle is the reference radius. The yellow circle on the coil shows the peak field location. The brown arrows show the net forces on each of the conductors.

The upper multipole table gives the multipole coefficients in T/cm^n (for US units). The lower table gives the multipole field ratios evaluated at the reference radius.

The five buttons on the upper right part of the screen are controlled by clicking with the mouse. ENTER PARAMETERS brings back up the series of windows for the user to enter parameters for a new design. OPTIMIZE brings up a series of windows for the user to start an optimization study. SAVE PARAMETERS is used to save the parameters for a

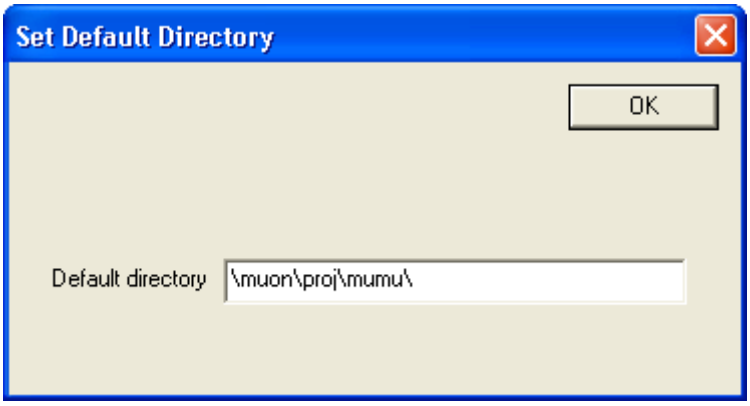
design to a file. AUXILIARY COMPUTATIONS brings up additional calculations of the midplane field, the magnetic field grid, the force distribution inside the coils, the magnetic lines of force, or the Fourier components around the reference circle. EXTRACT DATA creates external ascii files of selected information, such as the geometry or field data for a design.

The lower right hand box displays:

B0	normal dipole multipole at the center of the circle
A0	skew dipole multipole at the center of the circle
NI	amp-turns in the conductors
Bpk	peak field in coils
Fr	radial component of net force for block with maximum force
Fphi	azimuthal component of net force for block with maximum force

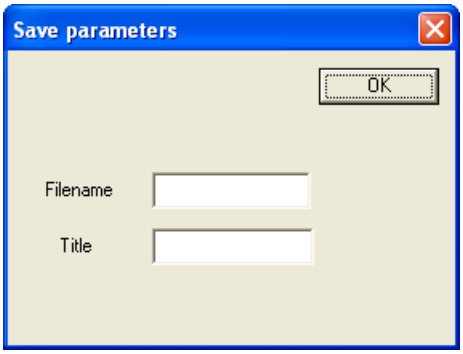
The last two quantities are replaced by Fx and Fy for rectangular conductors.

The user can set a default directory for reading and writing files by clicking on the File menu and selecting Set Default Directory. This will bring up the following dialog box.



4. Save parameters

This command is used to save the parameters for the current design.



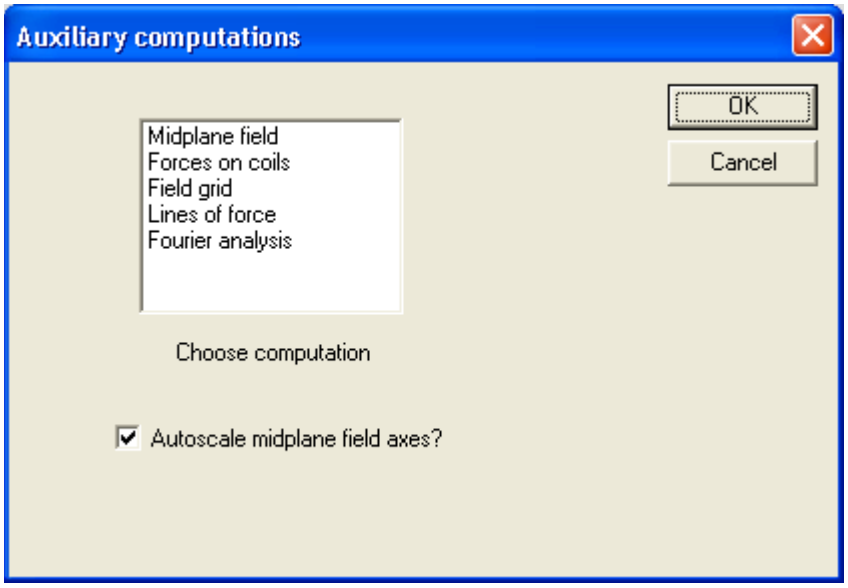
Besides the name of the file the user can enter some descriptive information as the title.

This file can also be created offline with a text editor. The format of the file is:

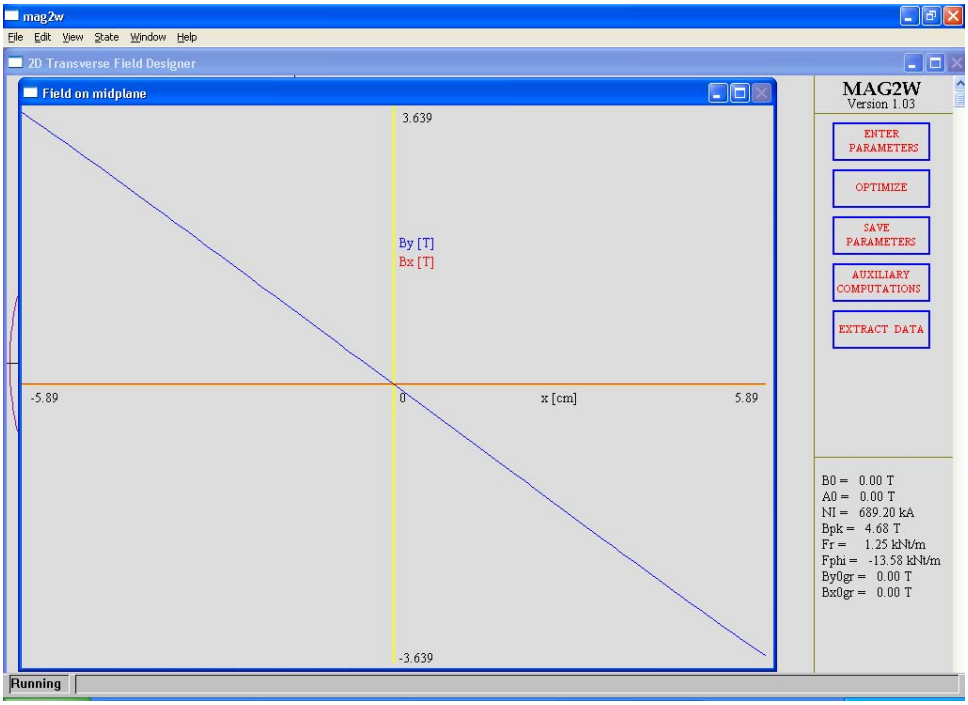
Title		(a80)						
Circle?		(L)		T: circular	F: rectangular			
If Circle=T then the following lines are:								
Mode		(I)		1: continuous	2:discrete			
Symm		(I)		1:dipole	2:quad	3:sextupole	4:none	
Iron?		(L)		T: yes	F: no			
Rbnd		(R)						
Rref		(R)						
nblocks		(I)						
For i=1,nblocks								
i	r1(i)	r2(i)	ph1(i)	ph2(i)	J(i)	tc(i)	ti(i)	Nt(i)
If Circle=F then the following lines are:								
Symm		(I)		1:dipole	2:quad	3:sextupole	4:none	
Wbnd		(R)						
Hbnd		(R)						
Rref		(R)						
nblocks		(I)						
For i=1,nblocks								
i	xll(i)	yll(i)	xur(i)	yur(i)	J(i)			

5. Auxiliary Computations

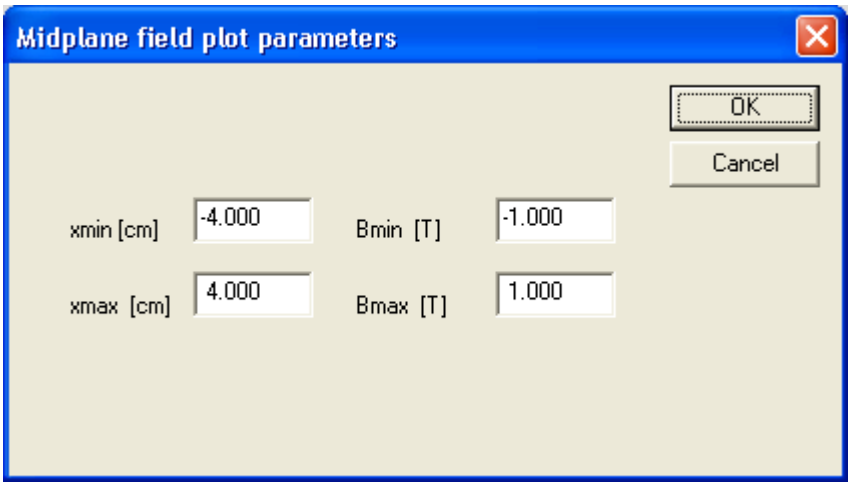
The AUXILIARY COMPUTATIONS button brings up a new window where the user may select additional calculations of the midplane field, the magnetic field grid, the force distribution inside the coils, magnetic lines of force, or Fourier components on the reference circle.



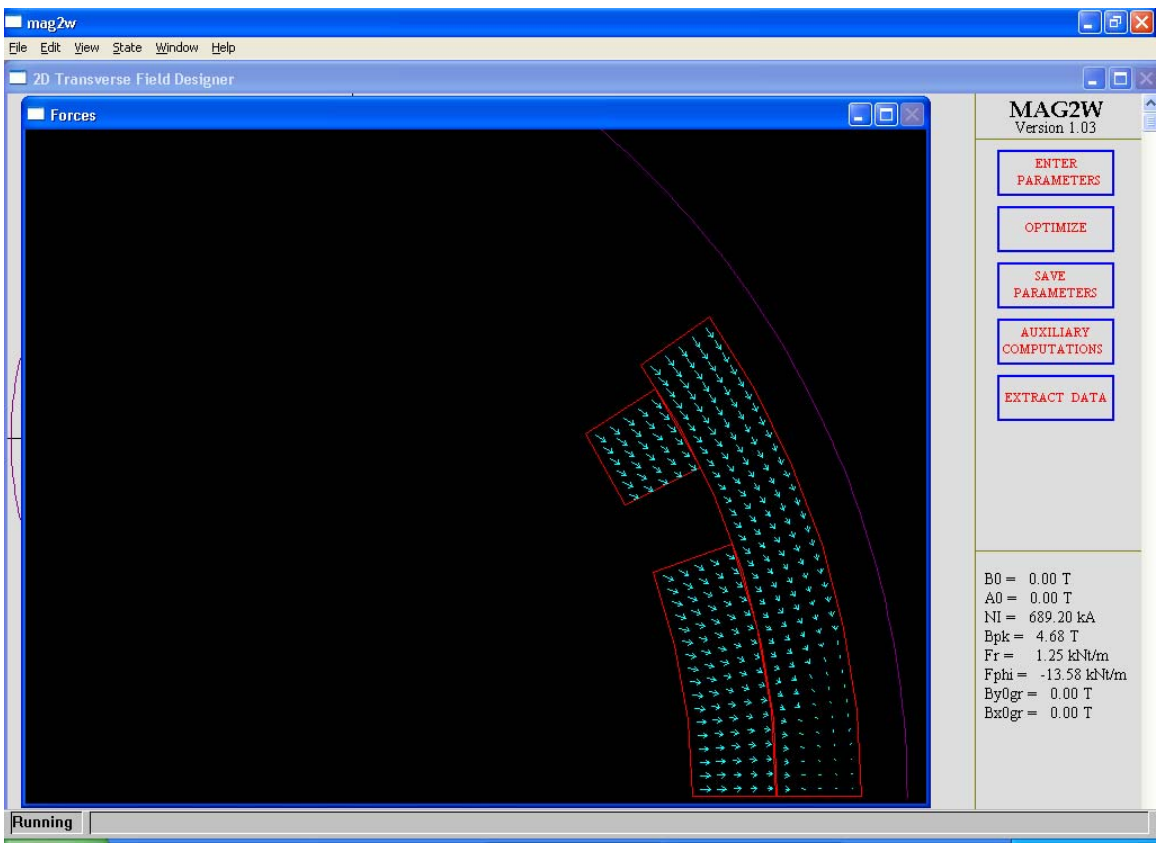
The user must select one of the items in the list and press OK. Here is an example of the midplane field plot for a quadrupole.



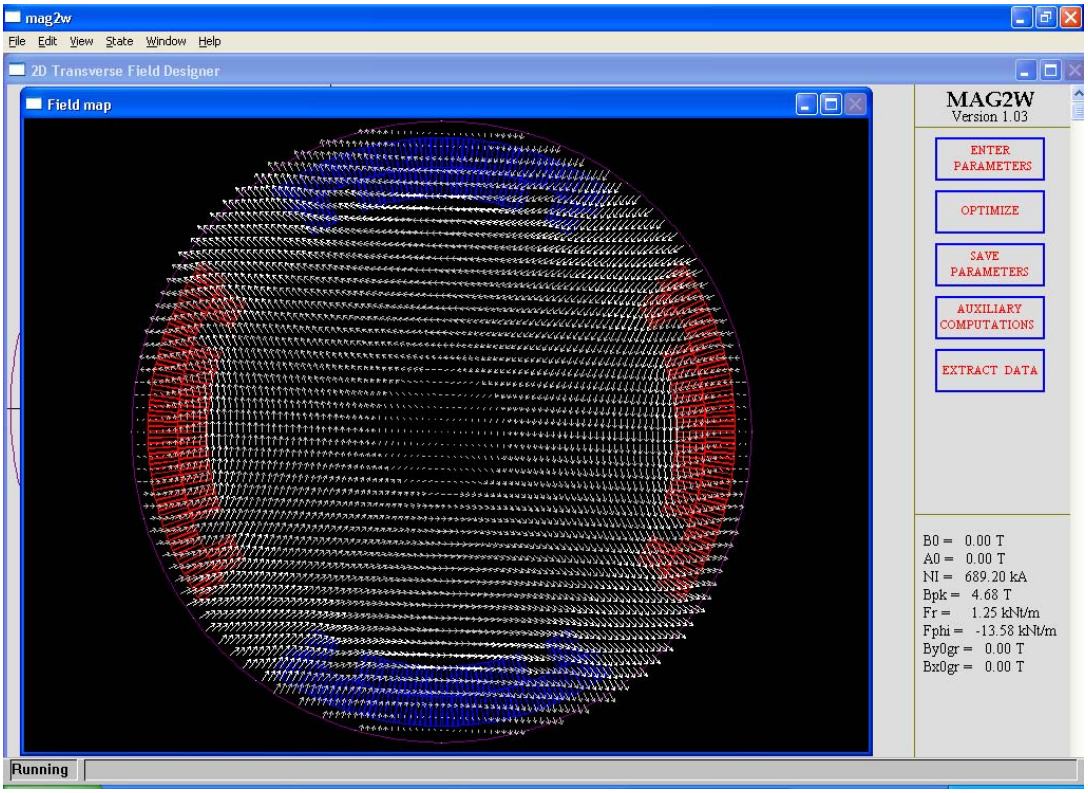
If the Autoscale Midplane box is not checked, a new window appears for the user to enter the axis limits.



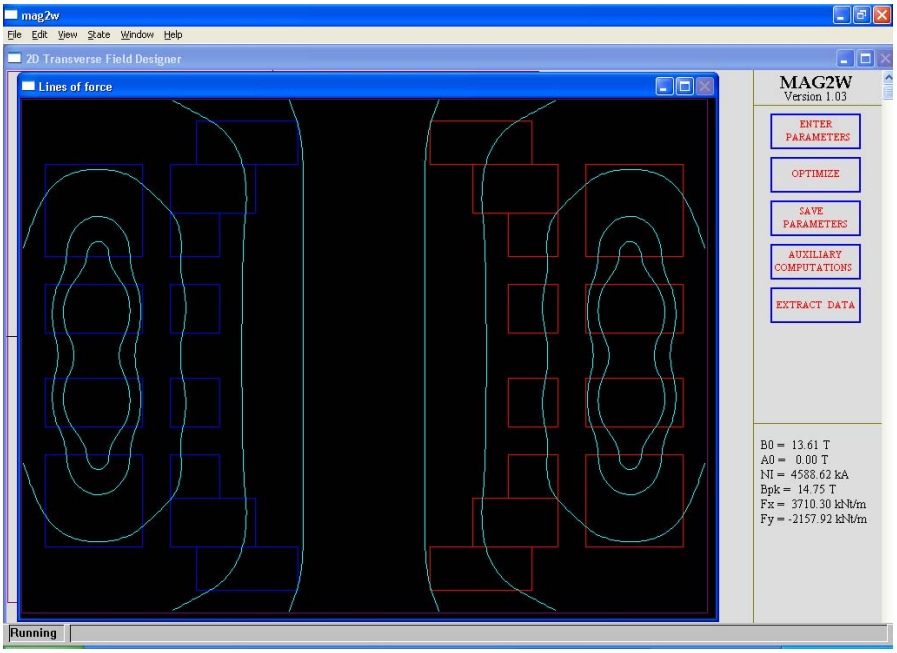
Here is an example of forces on the coil.



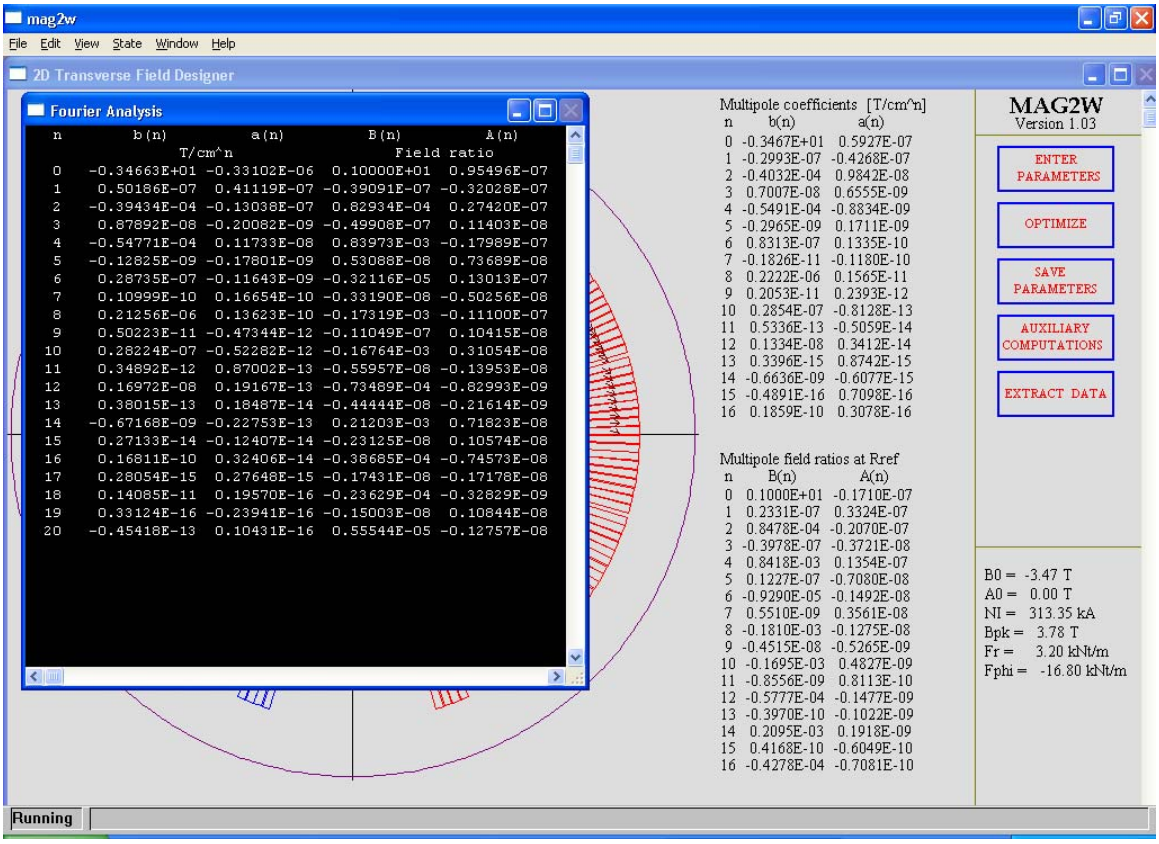
Here is an example of a magnetic field grids plot.



Here is an example of a lines-of-force plot for rectangular coils.



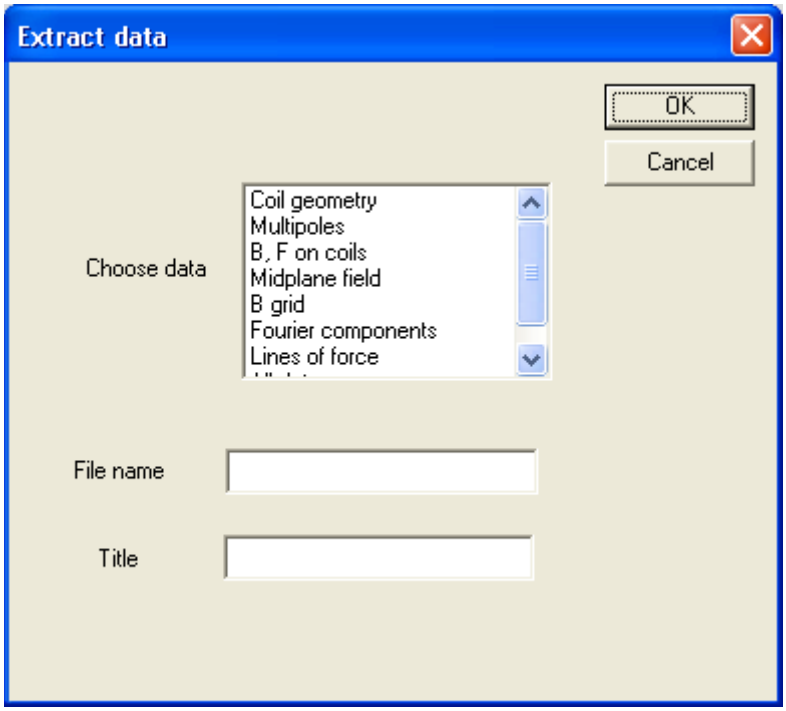
The Fourier analysis on the reference circle produces a table of Fourier coefficients.



The a_n coefficients are the cosine-like terms, while the b_n coefficients are the sine-like terms.

6. Extract Data

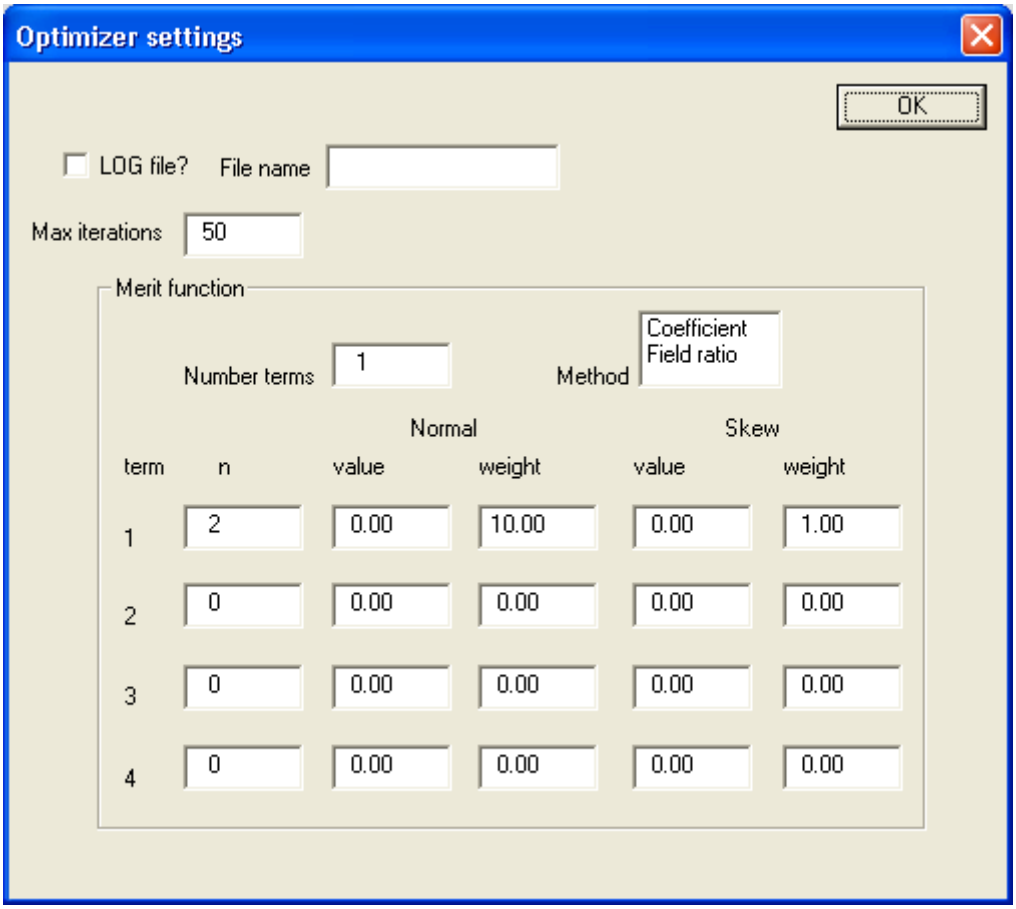
The EXTRACT DATA button can be used write selected information to an external file. This will bring up the following window.



The user can specify the file name where the data is written and can specify up to 80 characters of “title” information at the head of the file. All available information can be written to a single file by choosing All Data.

7. Optimization

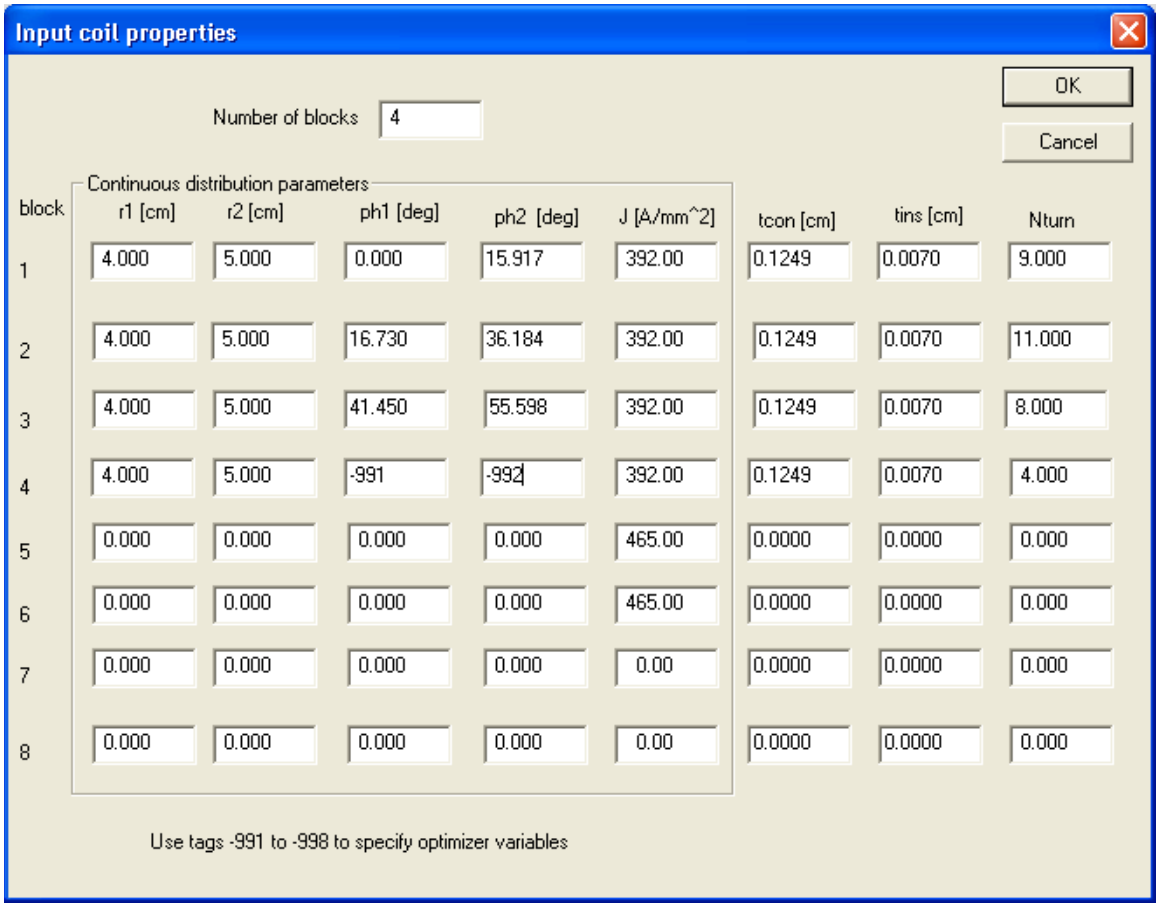
The first optimizer window controls the definition of the merit function and some general properties of the optimizer.



The progress of the optimization can be saved in an ascii log file. The maximum number of iterations roughly controls how long the optimizer will continue. The merit function is determined by the required values of up to four multipole orders *n*. The Method determines whether the value refers to multipole coefficients or to multipole field ratios. The weights determine the relative influence of different orders in computing the merit function. At least one weight must be non-zero.

After this window is closed the coil Input parameters windows appear again.

In the second Input window, shown here for circular geometry,



Input coil properties

OK

Cancel

Number of blocks 4

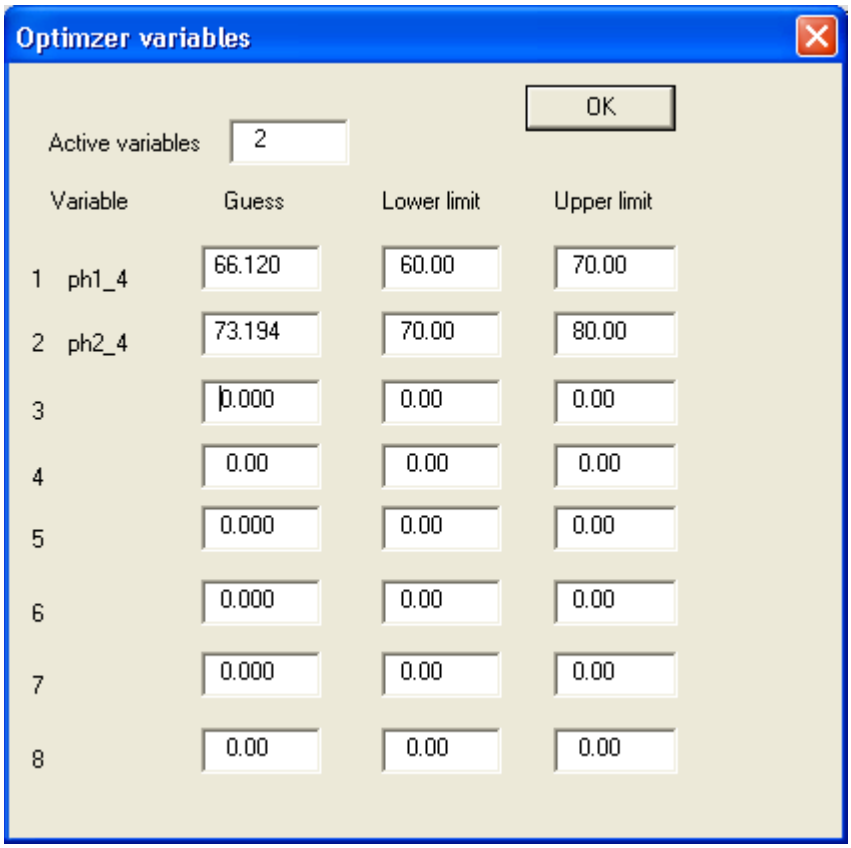
Continuous distribution parameters

block	r1 [cm]	r2 [cm]	ph1 [deg]	ph2 [deg]	J [A/mm^2]	tcon [cm]	tins [cm]	Nturn
1	4.000	5.000	0.000	15.917	392.00	0.1249	0.0070	9.000
2	4.000	5.000	16.730	36.184	392.00	0.1249	0.0070	11.000
3	4.000	5.000	41.450	55.598	392.00	0.1249	0.0070	8.000
4	4.000	5.000	-991	-992	392.00	0.1249	0.0070	4.000
5	0.000	0.000	0.000	0.000	465.00	0.0000	0.0000	0.000
6	0.000	0.000	0.000	0.000	465.00	0.0000	0.0000	0.000
7	0.000	0.000	0.000	0.000	0.00	0.0000	0.0000	0.000
8	0.000	0.000	0.000	0.000	0.00	0.0000	0.0000	0.000

Use tags -991 to -998 to specify optimizer variables

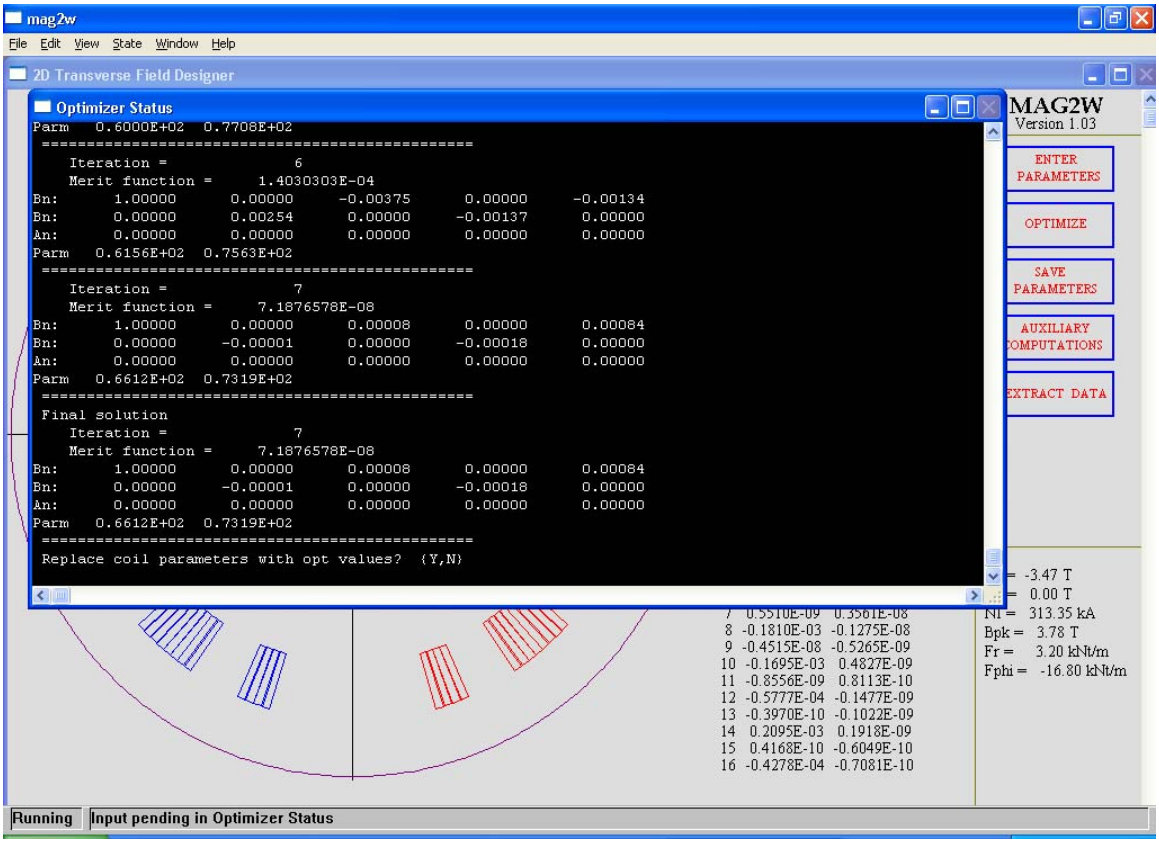
the user enters the tags from -991 to -998 to indicate which parameters to vary in the optimization. The example shown ere has two variables: the start and end angles of the fourth block.

At this point a second optimizer window appears where the user can specify an initial guess and lower and upper limits for each of the optimizer variables.



One must enter an initial guess and lower and upper limits for each of the active variables.

Once the optimization begins the progress is displayed in another window.



At completion the user must type Y to replace the current solution with the optimizer results, or N to ignore it.