USER MANUAL

APPLICATION NAME

EPCOS MAGNETIC DESIGN TOOL

LAST APPLICATION VERSION	**5.1.0.**
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CONTENTS

1. Introduction

1.1. Fundamentals

The Magnetic Design Tool provides the convenient access to the material data of the available TDK ferrite materials and their integration in the process of design in digital form. The parameters on which the design tool is based, such as hysteresis loop, power loss, initial permeability, amplitude permeability and complex permeability are formed by the measurement data of the available TDK ferrite materials. These measurement data can be represented as a graph and compared to one another.

The graphs created can be printed, or pasted into other Windows applications via the clipboard. A simple editor lets you take notes relating to the selection process as you are working with the Magnetic Design Tool.

1.2. Subprograms

1.2.1. Material Form

In dependence of the material selected, this subprogram serves to graphically represent

- a hysteresis loop
- the initial permeability vs. temperature
- the power loss vs. frequency, flux density, temperature and the performance factor
- the amplitude permeability vs. flux density or field strength
- the complex permeability vs. frequency in serial and parallel representation

1.2.2. Core Form

In dependence of the material and core form selected, this subprogram serves to:

- obtain a data overview,
- calculate the AL-value in dependence of the air gap (or vice versa)
- represent the effective permeability over temperature,
- determine the transferable power Ptrans
- calculate third harmonic distortion under circuit conditions
- calculate the appropriate air gap, Al value and the number of turns for a given permeability drop p [%] , representing the curve of inductance or permeability vs. DC-bias
- display the ratio of the AC- to DC-resistance vs. frequency.

1.2.3. Graph Control

In the Graph Control window, the representation of the graphs can be defined, the represented graphs can be printed, and they can be pasted into other Windows applications via the Clipboard.

This window can be opened from any subprogram supporting graphic representation.

1.2.4. Starting the Program

- Start the program by double-clicking on the *MDT* icon on the desktop.

The program will be started with a blank editor window opened.

1.2.5. Exiting the Program

- Select the *Exit* menu item in the *File* pull-down menu. The program will be terminated.

2. Fundamentals on Operation

The basic operational procedures and the button assignments for the subprograms Material Properties and Core Calculations are identical. For this reason, they are described globally in this context.

2.1. Selection of the Material / Core

Drop-down menus for selecting the desired material and core form. Only those materials and core forms can be selected for which the desired representation (calculation) is performable.

2.2. Data Point Reader

Position the mouse pointer on a point of a measured curve on the screen and click on it with the left mouse button. The corresponding measured value will be displayed in the Data Point Reader window.

2.3. Graph Control

Clicking on these buttons calls the Graph Control window, in which the representation type of the graphs can be defined, the graphs displayed can be printed, and in which they can be made available for other Windows applications via the Clipboard.

2.4. Graph Output

The graphs are output in this window area. By selecting multiple materials and/or core forms, graphs can be superimposed and thus conveniently compared.

2.5. Input Fields

Data for calculations can be entered in fields underlayed in white. The input is confirmed by pressing the Return key.

2.6. Output Fields

Output fields are underlayed in grey. They merely serve for displaying the results of calculations or measured values and cannot be modified.

3. Material Form

3.1. Hysteresis Loop

The program can represent the hysteresis loops at the temperatures of T = 25 °C and T = 100 °C for all available TDK ferrite materials that are included in the data book. For every point of the graph, a pair of values H, B can be displayed.

3.1.1. Procedure

- Click on the ***Material Form*** button in the main window. The *Material data* window will be opened.
- Select ***Hysteresis***.
- Select the desired material.
- Select the desired temperature.

The hysteresis loop will be displayed.

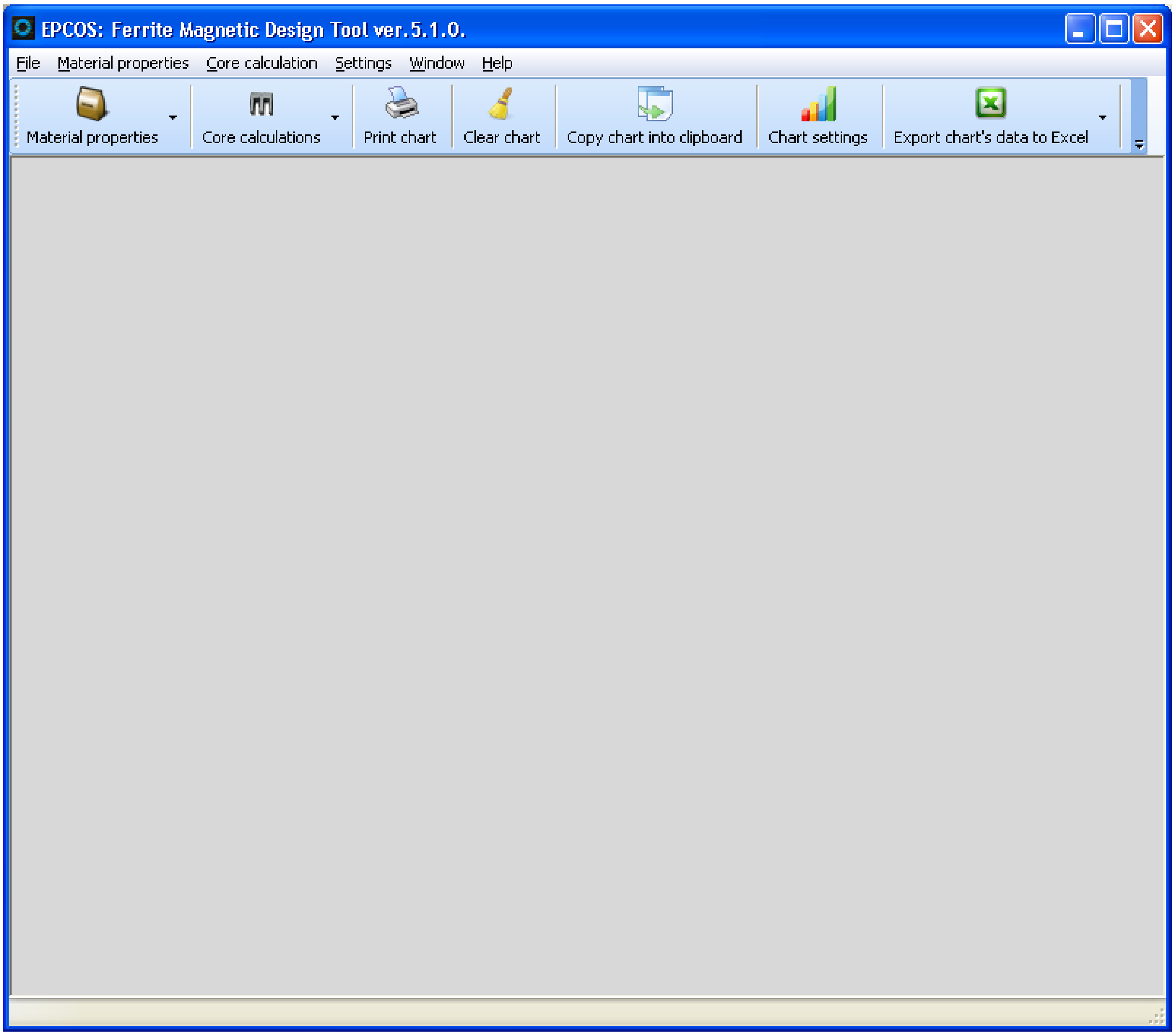

Fig. 3-1 – Hysteresis loop

Move mouse cursor on a point of the graph to view the associated pair of values B and H in the Data Point Reader. If you want to zoom in the graph, click on the graph by left mouse button and select area to zoom in. If you want to zoom out the graph to default scale, click on the graph by left mouse button and move the mouse to the left upper corner of the graph. If you click on the graph by right mouse button, you can move in current scale of the graph.

3.1.2. Zoom Function

To be able to view the hysteresis loop of the ferrites more closely, the program provides a zoom function (only valid for power materials in this version).

Zoom in - Click into the area of the graph with the left mouse button.

Zoom out - Click into the area of the graph with the right mouse button.

3.2. Initial Permeability

For all available TDK ferrite materials, the initial permeability as a function of the temperature T can be displayed. For every point of the graph, a pair of values T, µi can be displayed. It is possible to display multiple curves in one graph. This provides an optimal material comparison.

3.2.1. Procedure

- Click on the *Material Form* button in the main window. The *Material data* window will be opened.
- Select ***µi vs. T***.
- Select the desired material.

The initial permeability as a function of the temperature will be displayed.

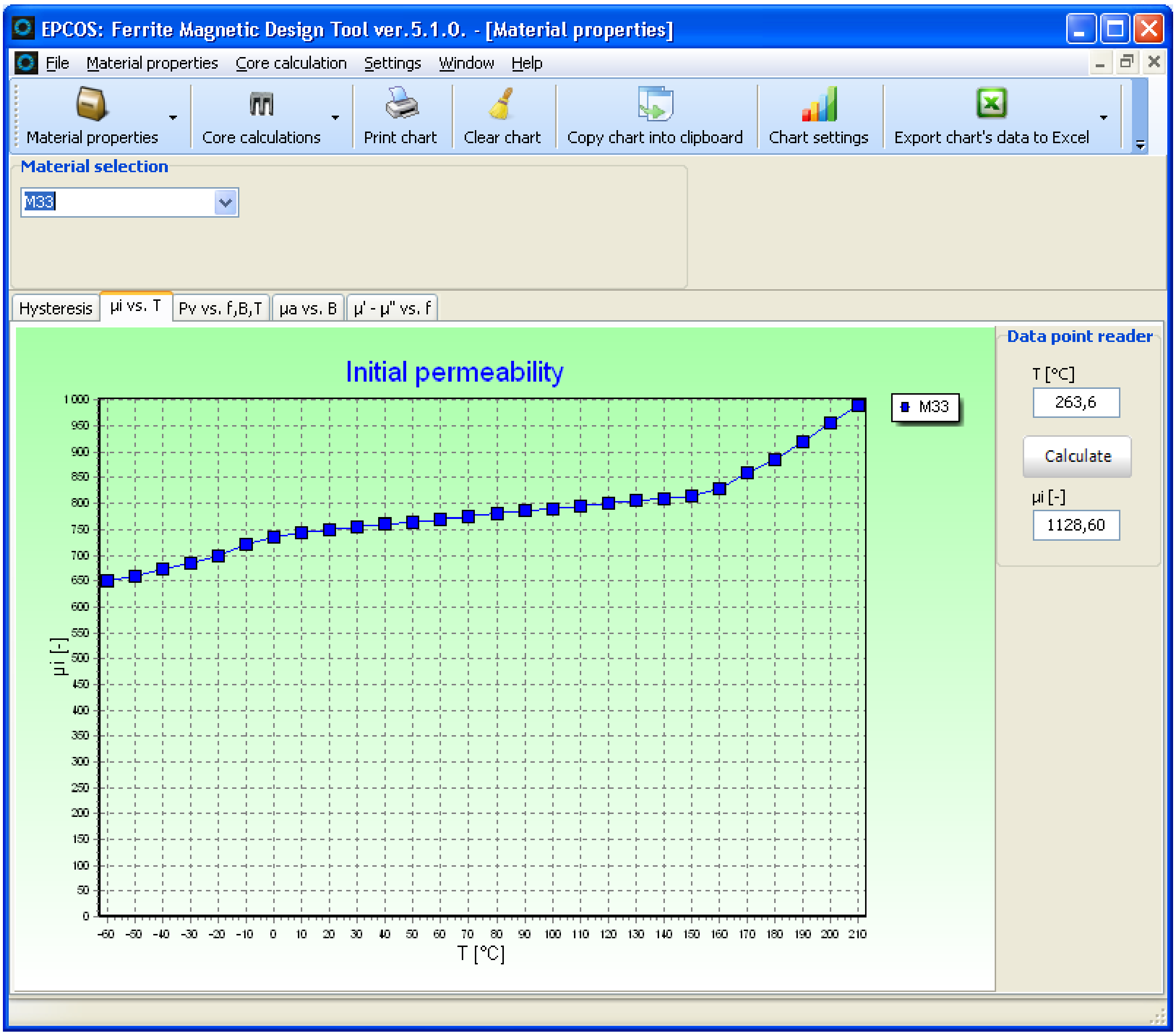

Fig. 3-2 - Initial permeability

- Click on measuring points in the curve to view the value µi for a specific temperature in the *DataPoint Reader*.

3.2.2. Intermediate Values of µi

It is also possible to calculate intermediate values of µi relating to the measuring points (linear interpolation).

- Enter the temperature T [°C] in the input field and click the yellow “calculate” button. The value calculated for the selected material will be displayed in the µi output field.

3.3. Power Loss

For all available TDK power materials, the power loss per volume and per mass can be represented as a function of the temperature T, the frequency f and the flux density B. The number of measurement data available in the program exceeds the number of data specified in the data book by far. It is possible to display multiple curves in one graph. This provides an optimum material comparison.

3.3.1. Procedure

- Click on the *Material Form* button in the main window. The *Material data* window will be opened.
- Select *Pv vs. f, B, T*.
- Select the desired material.
- Define the parameters that are to be presented on the X- and Y-axes.
- Select the frequency f, the flux density B or the temperature T (depending on the setting of the X-axis).

Depending on the setting, the power loss will be displayed as a function of T, f or B.

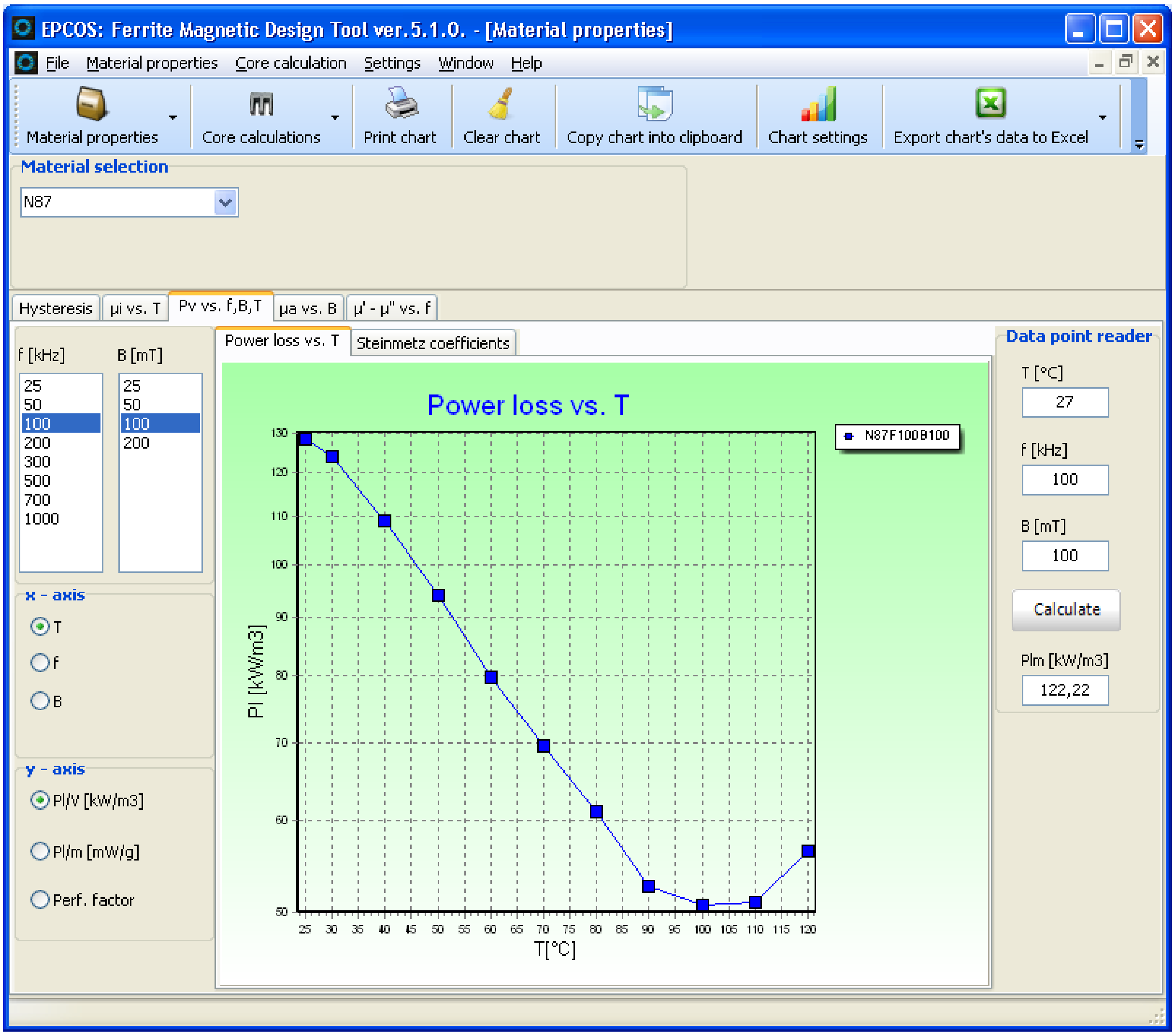

Fig. 3-3 - Power loss vs. T

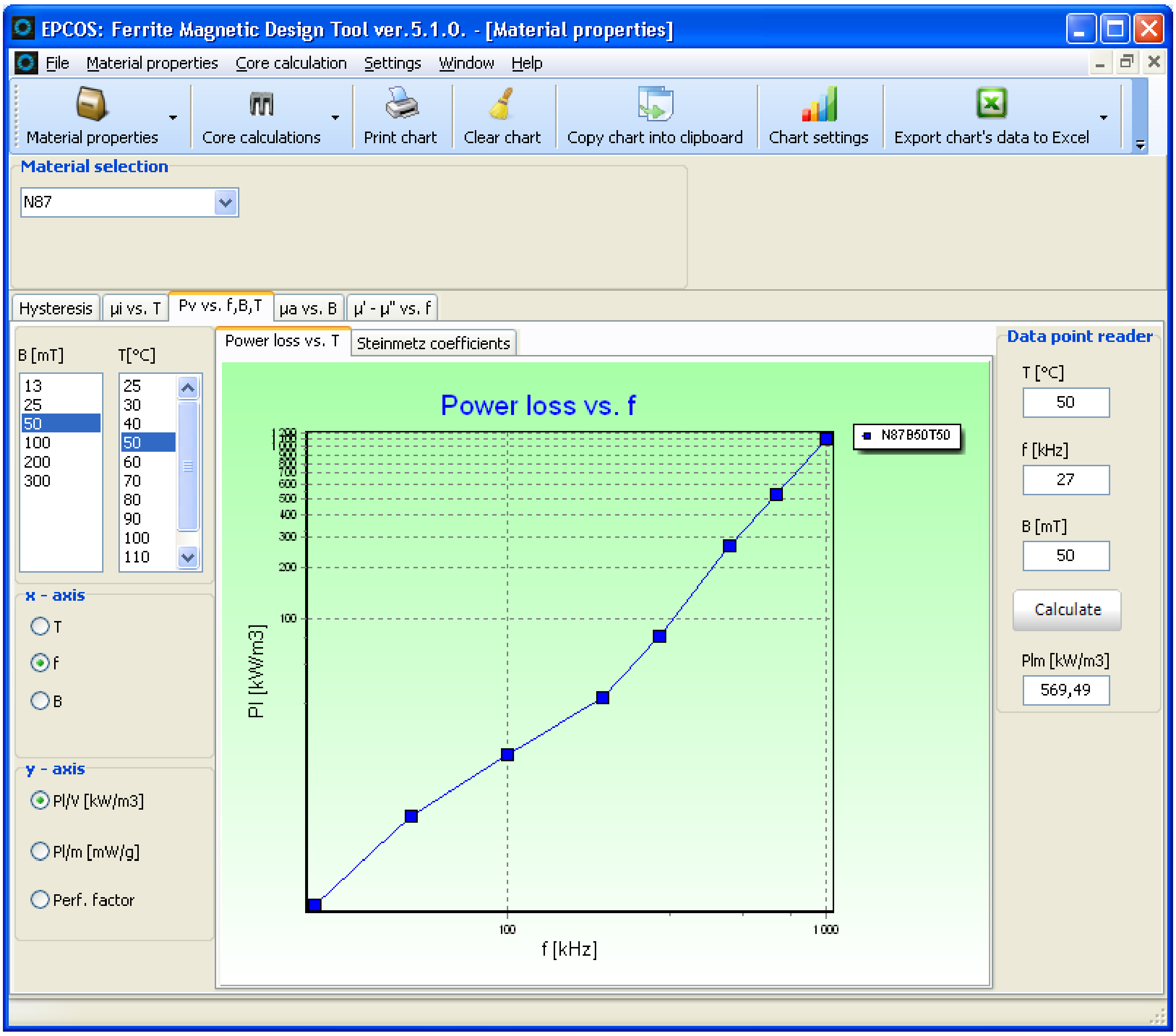

Fig. 3-4 - Power loss vs. f

- Click on measuring points to view the associated pair of values in the *Data Point Reader*.

3.3.2. Measured values of PL

The measured power losses for appropriate combinations of temperature, frequency and flux density can also be displayed.

- Enter the temperature T [°C], the frequency f [kHz] and the flux density B [mT] in the input fields.

The measured values for the selected material will be displayed in the P_L output field.

3.3.3. Steinmetz coefficients

You can see “Steinmetz coefficients” for power materials on the page “Steinmetz coefficients”.

The losses P_C in W/set in a soft ferrite core may be expressed as

$$P_C = K_F * V_e * p_{v\sin} * \left(\frac{f}{f_b}\right)^{\alpha} * \left(\frac{B}{B_m}\right)^{\beta}$$

Where:

- f (kHz) is the actual operating frequency and B (mT) the actual operating peak sinusoidal flux density at an operating temperature T_{op} (°C);
- p_{vsin} is the loss density in kW/m^3 at temperature T_{op}(°C), frequency f_b (kHz) and peak sinusoidal flux density B_m (mT);
- V_e (mm^3) is the magnetic volume of the core;
- α is the Steinmetz exponent for frequency and β the Steinmetz exponent for flux density for the ferrite material at T_{op};
- p_{vsin} is measured on standard ring cores;
- K_F is a multiplication factor for the particular core shape in use;

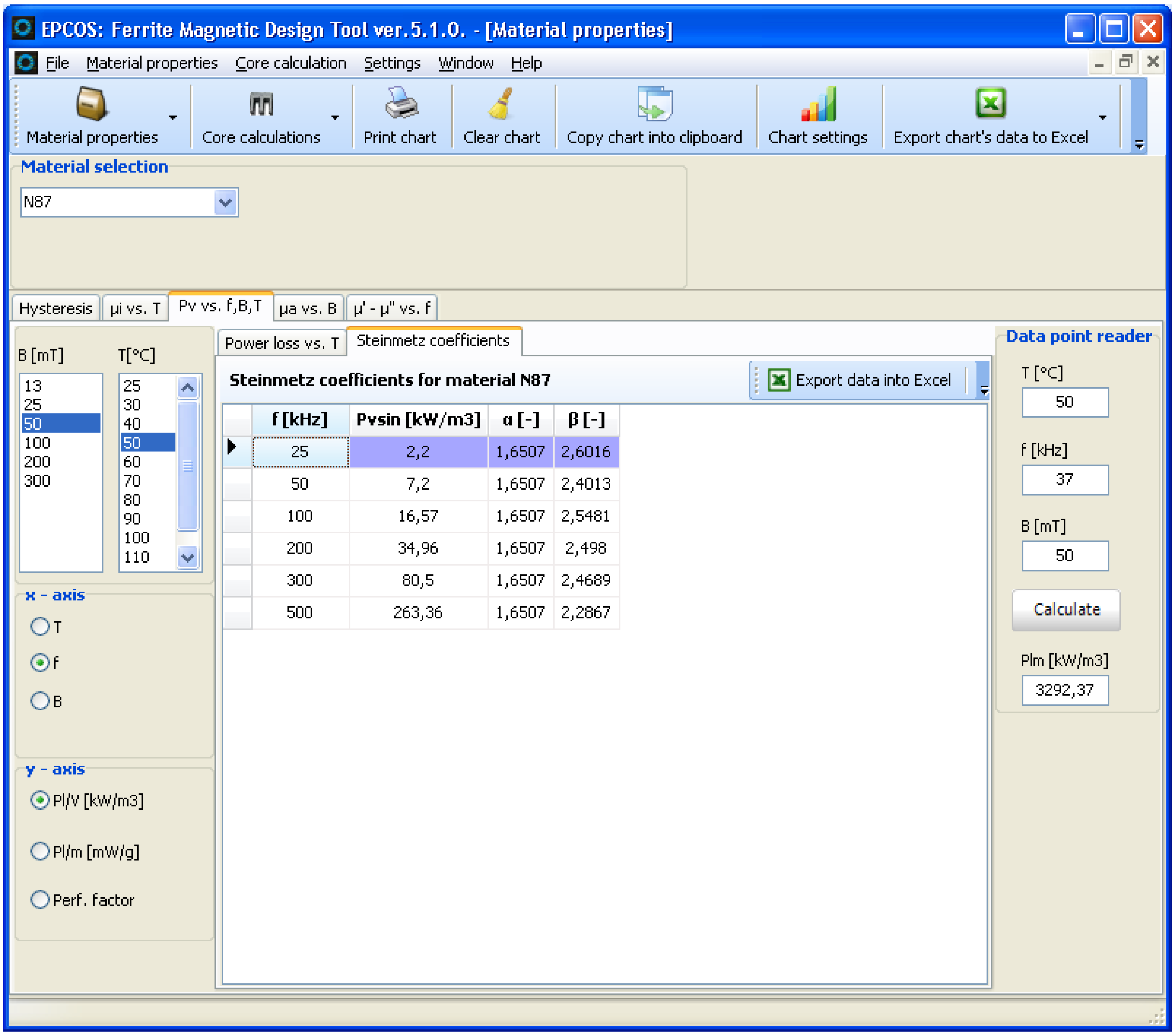

Fig. 3-5 Steinmetz coefficients

These coefficients you can simply export to MS Excel by clicking on the button "Export data into Excel".

3.3.4. Amplitude Permeability

For all available TDK power materials, the amplitude permeability as a function of the flux density B or the field strength H can be represented at the temperatures of T = 25 °C and T = 100 °C. For every point of the graph, a pair of values B, µa or H, µa can be displayed. It is possible to display multiple curves in one graph. This provides an optimum material comparison.

3.3.5. Procedure

- Click on the *Material Form* button in the main window. The *Material data* window will be opened.
- Select ***µa vs. B***.
- Select the desired material.
- Select the desired temperature.
- Select the measurand (B, H) that is to be represented on the X-axis.

The amplitude permeability as a function of the flux density B or of the field strength H will be displayed.

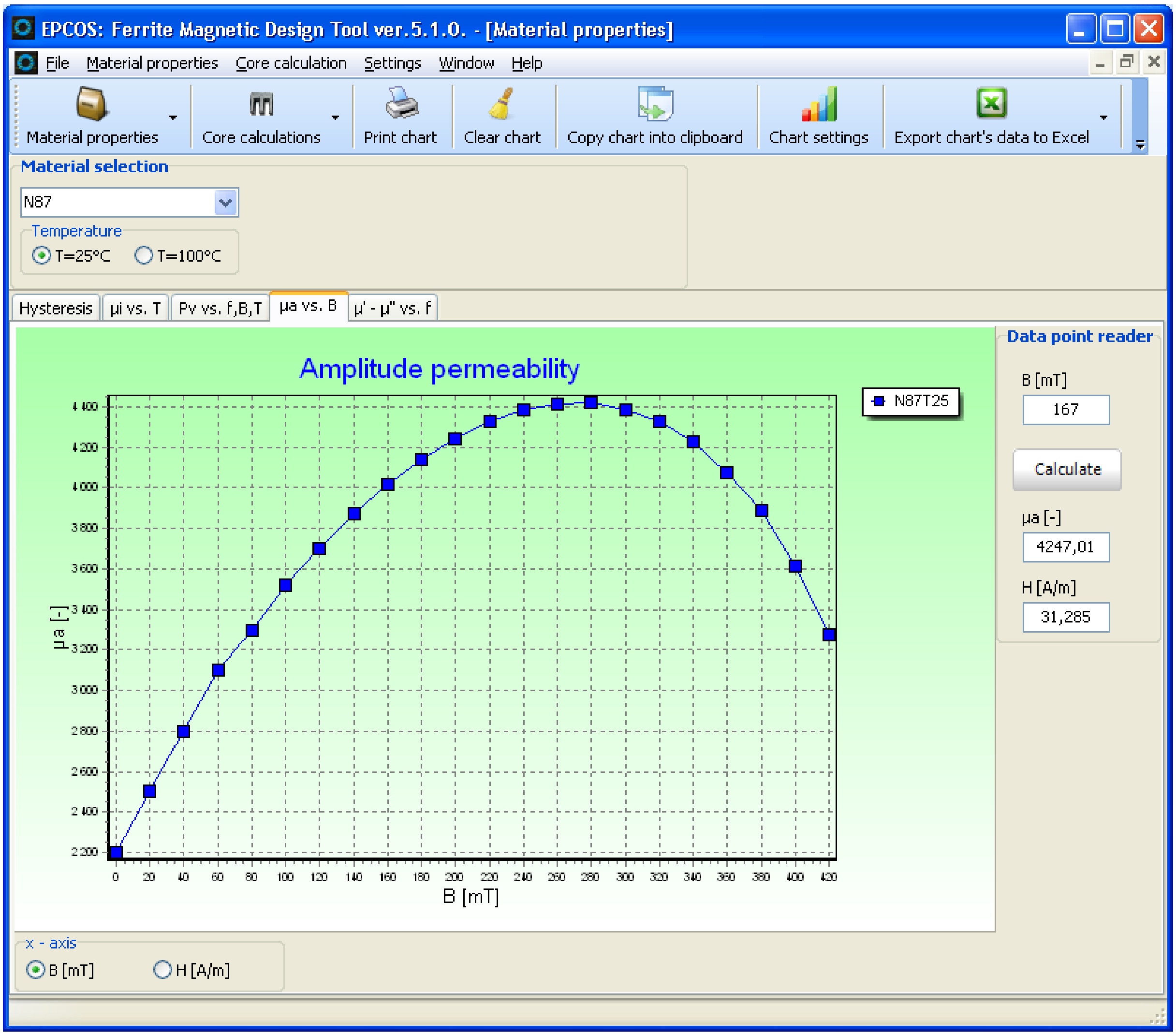

Fig. 3-6 - Amplitude permeability

- Click on a measuring point in the curve to view the associated pair of values B, µa or H, µa in the Data Point Reader.

3.3.6. Intermediate values of µa

It is also possible to calculate intermediate values of µa relating to the measuring points. The measurand you can enter depends on the setting for the X-axis.

- Enter the desired value in the input field (H or B) and click the yellow "calculate" button.

The value calculated for the selected material will be displayed in the µa output field.

3.4. Complex Permeability

For all available TDK materials, the complex permeability can be represented as a function of the frequency. You can select one of seven display types µs' (f), µs'' (f), µp' (f), µp'' (f), gp(f), tanδ/µi(f) or Z_N(f). It is possible to display multiple curves in one graph. The different parameters provide an optimum material comparison for various applications:

- the relative loss factor tan□/µ for filter inductors with high Q
- the parallel conductance gp(f), which is directly proportional to the insertion loss, for broadband transformers
- the normalized impedance Z_N(f) for EMI suppressors

The relationship among the different parameters is given as follows:

$$\mu_p'^2(f) = \frac{\mu_s'^2(f) + \mu_s''^2(f)}{\mu_s'^2(f)}$$

$$\mu_p''^2(f) = \frac{\mu_s'^2(f) + \mu_s''^2(f)}{\mu_s''^2(f)}$$

$$\frac{\tan\delta(f)}{\mu_i} = \frac{1}{\mu_i} \cdot \frac{\mu_s'(f)}{\mu_s''(f)}$$

$$g_p(f) = \frac{1}{f \cdot \mu_p''(f)}$$

$$Z_N(f) = 2 \cdot \pi \cdot f \cdot \mu_0 \sqrt{\mu_s'^2 + \mu_s''^2}$$

3.4.1. Procedure

- Click on the *Material Form* button in the main window. The *Material data* window will be opened.
- Select ***µ'-µ'' vs. f*** .
- Select the desired material.
- Select whether µs' (f), µs'' (f), µp' (f), µp'' (f), gp(f), tan□/µi (f) or Z_N(f) are to be represented.

The graph will be displayed.

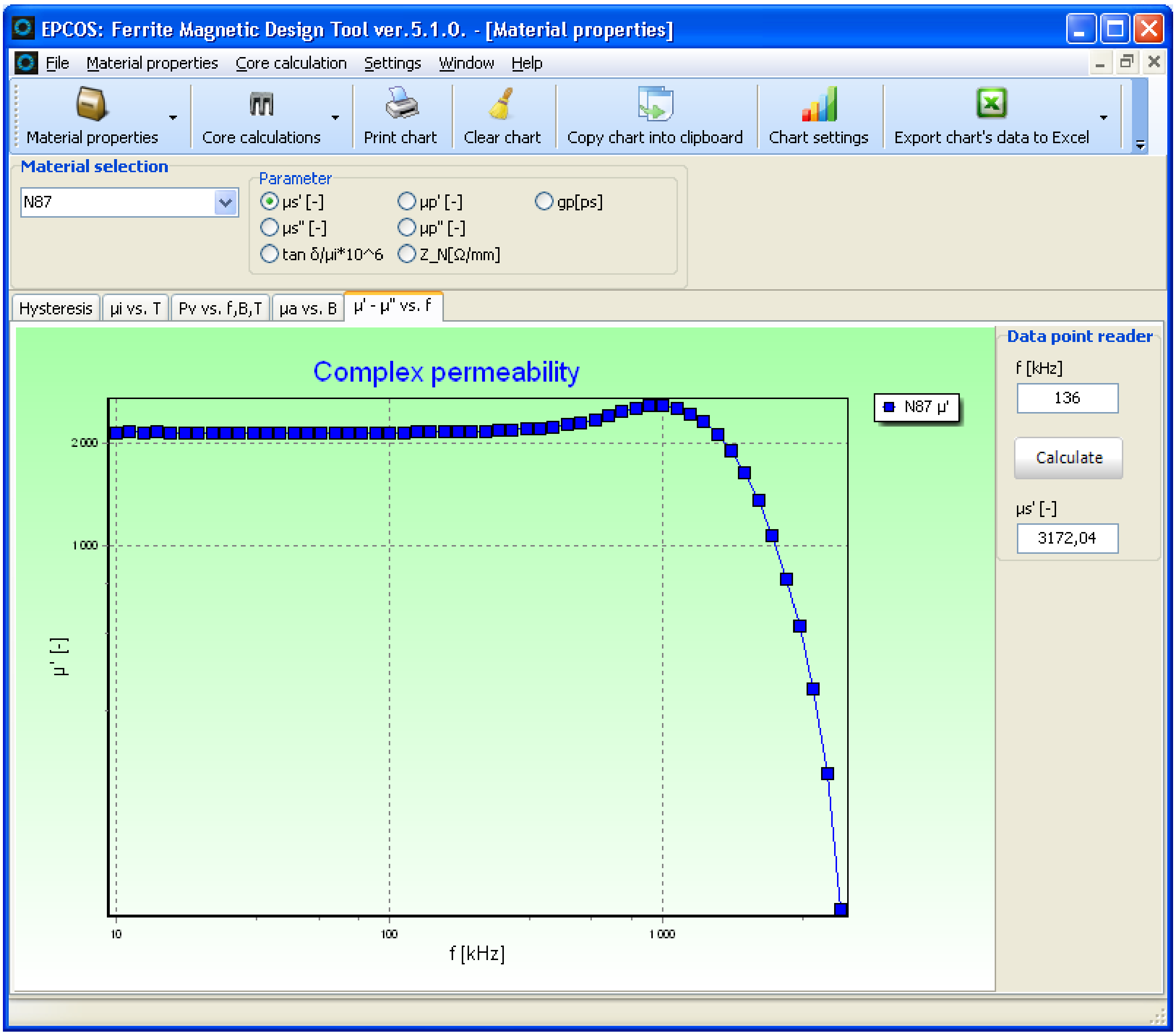

Fig. 3-7 - Complex permeability

- Click on measuring points in the curve to view the associated pairs of values in the Data Point Reader.

3.4.2. Intermediate values of µs' (f), µs'' (f), µp' (f), µp'' (f), gp(f), tanδ/µi (f) or Z_N(f)

- Enter the desired frequency in the input field and click the yellow "calculate" button. µ' (f), µ'' (f) and tan□/µi will be displayed.

4. Core Form

4.1. Effective Permeability

For all available TDK materials, the core-form-specific μe(T) characteristics based on the μi(T) material curve (measured on ring cores) can be calculated. This calculation is performed according to the well-known equation:

$$\frac{1}{\mu e} = \frac{1}{\mu i} + \frac{s}{le}$$

It is possible to display multiple curves in one graph. This provides an optimum comparison (e.g. change of the air gap).

4.1.1. Procedure

- Click on the *Core Form* button in the main window. The *Core data* window will be opened.
- Select ***μe vs. T***.
- Select the desired core.
- Specify the core form (optionally: low profile, with hole). *Note:* Please observe that not all combinations are valid (e.g. in low profile, only RM cores are available). Values will not be output if an invalid combination was specified.
- Select the desired material.
- Select the type of representation μe(T) or (μe(T) - μe(T1))/(μe(T).
- Enter the desired air gap in the *s* field.

The effective permeability as a function of the temperature will be displayed.

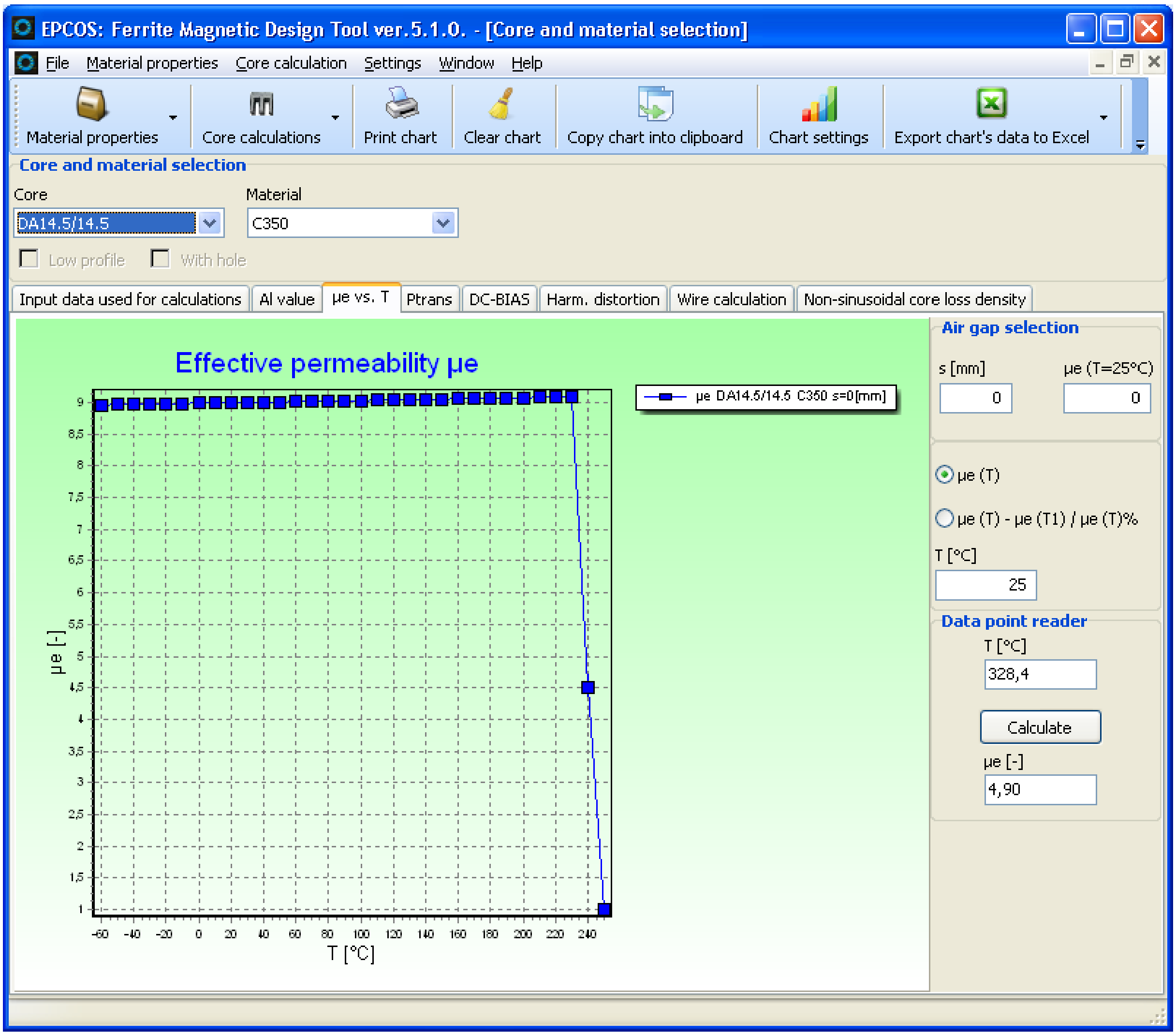

Fig. 4-1 - Comparison of the effective permeability using different air gaps.

- Click on points in the curve to view the associated pairs of values T, µe in the *Data Point Reader*.

4.2. Transferable Power P_{trans}

For all power materials and most cores, the transferable power Ptrans can be determined.

4.2.1. Procedure

- Click on the *Core Form* button in the main window. The *Core data* window will be opened.
- Select $\boldsymbol{P_{trans}}$.
- Select the desired core.
- Specify the core form (optionally: low profile, with hole). *Note:* Please observe that not all combinations are valid (e.g. in low profile, only RM cores are available). Values will not be output if an invalid combination was specified.
- Select the desired material.

- Correct for the default thermal resistance Rth value (free-air convection), if a better figure is known for your application.
- Enter the desired values in the dTCu, dTFe and f input fields.
- Correct for the default copper space factor fCu=0.4 if a better figure is known for your application.
- If a wire calculation on the selected core type has been performed previously, click the “get Rac/Rdc” button to consider proximity and skin effects in the Ptrans calculation.
- Select the appropriate converter type in the pull down menu.
- Ptrans will be displayed in the output field after pressing the “Calculate” button.

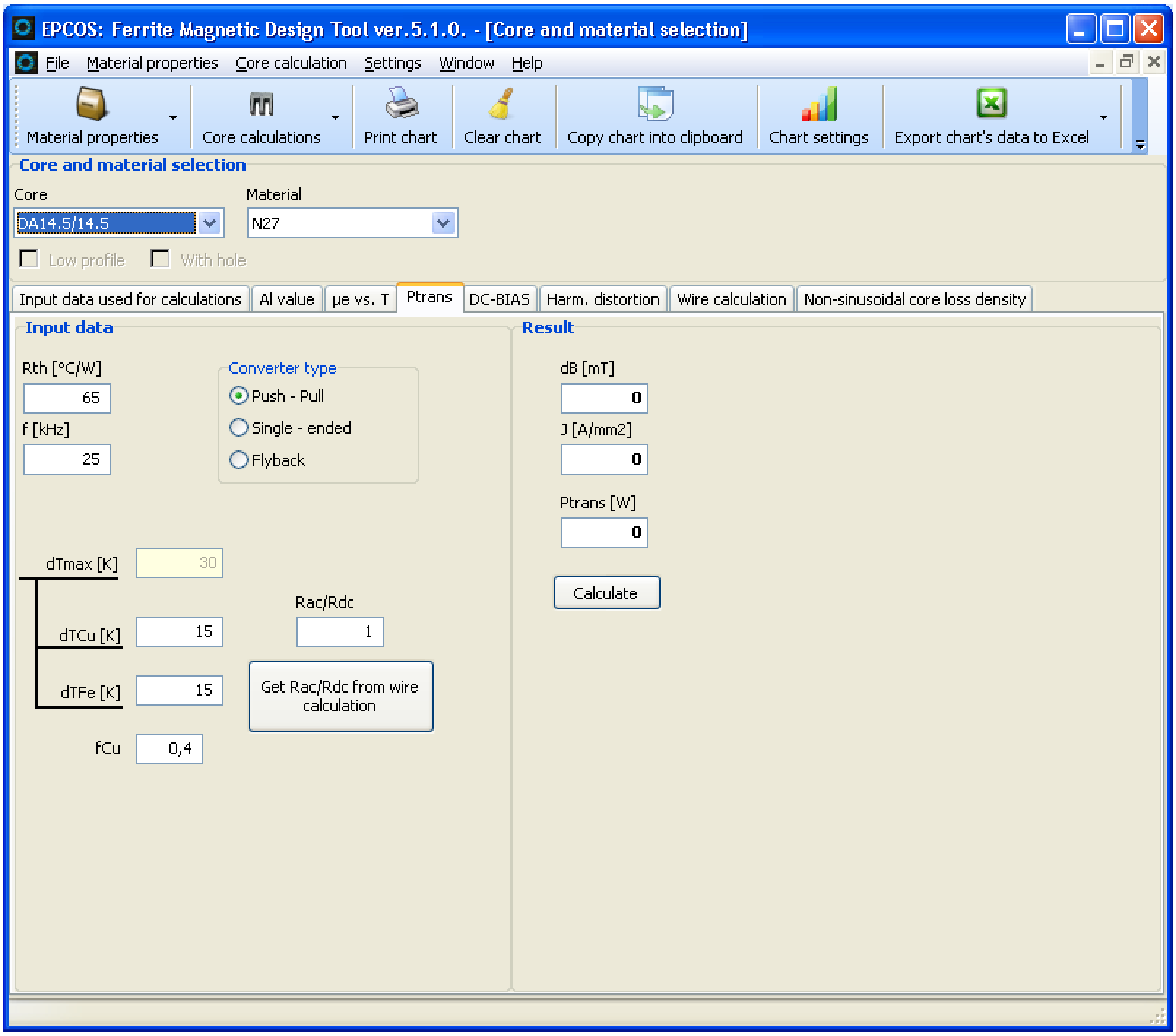

Fig. 4-2 - Transferable power Trans

4.2.2. Further description of the input fields

fCu: copper space factor

dTCu: copper temperature rise [K]

dTFe: ferrite temperature rise [K]

The transferable power Ptrans of transformers can be calculated by the following approximation:

$$(1) \quad P = C \cdot f \cdot \Delta B \cdot S \cdot f_{cu} \cdot A_N \cdot A_e$$

The constant C relates to the operation mode which is:

C=1 in push-pull converters

C=0,71 in single-ended converters

C=0,62 in flyback converters 1) .

Further quantities in equation (1) are the switching frequency f, the sweep of flux density ΔB, the current density S, the winding cross section AN and the effective area Ae.

4.3. Data Overview

For all TDK materials and core shapes, various digital data are represented in the form of a table.

4.3.1. Procedure

- Click on the *Core Form* button in the main window.

The *Core data* window will be opened. Select ***Input data used for calculations***.

Fig. 4-3 - Input data used for calculations

- Select the desired core.
- Specify the core form (optionally: low profile, with hole). *Note:* Please note that not all combinations are valid (e.g. in low profile, only RM cores are available). Values will not be output if an invalid combination was specified.
- Select the desired material.

Here you have 2 possibilities for selecting core:

1. You can use predefined TDK core from installed MS Access database – page “Default data”.
2. You can define your own core on page “User’s data”.

4.3.2. Creating custom core’s data

Select some core from combo box “Core” and click on the button “Create user data from selected core” - see fig. 4-4.

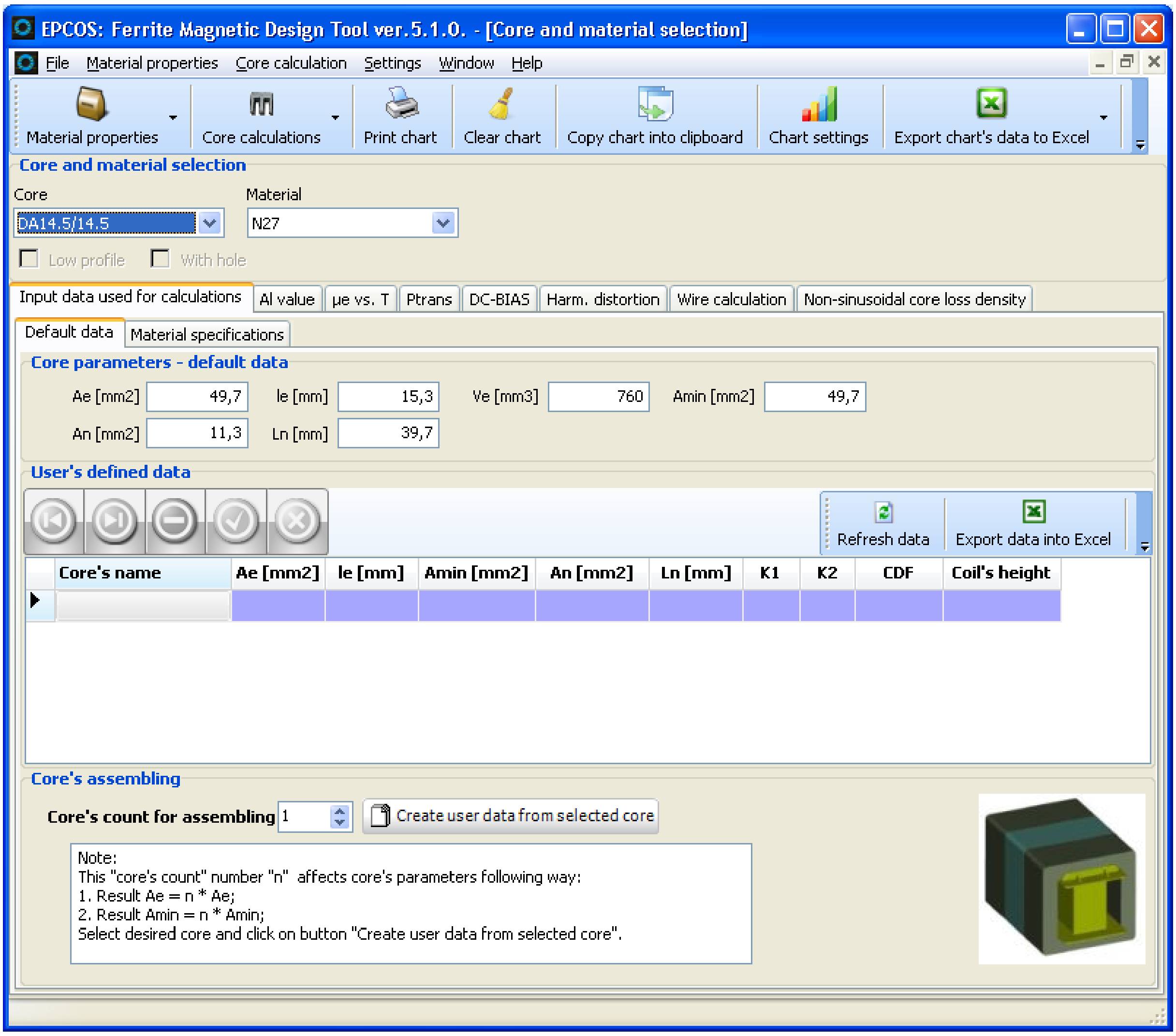

Fig. 4-4 Creating of user's core data

Then you can edit required parameters in "User's defined data grid".

4.3.3. Core's assembling (stacking)

If you want to stack cores at each other, you can enter the count of these cores in field "Core's count for assembling". Default value is 1. The count "n" has following influence on core's calculation:

1. Result $A_e = n * A_e$;
2. Result $A_{min} = n * A_{min}$;

Notice: This core's assembling has sense only for cores E, U, U+I, R. Then click on button "Create user data from selected core". These data will be copied into local file and "Ae" and "Amin" will be calculated by above mentioned formulas.

4.4. AL-values

For all available TDK materials, the following calculations can be performed using the calculator:

- Al as a function of the air gap and vice-versa without taking into account the fringe flux
- Al as a function of the air gap and vice-versa using the K-factors (only for EE-, EC-, ER, ETD-, EFD-, EPF-, and ELP-cores in N27, N67, N87)
- The inductance as a function of the Al value and vice-versa

4.4.1. Procedure

- Click on the *Core Form* button in the main window. The *Core data* window will be opened.
- Select ***AL-value***

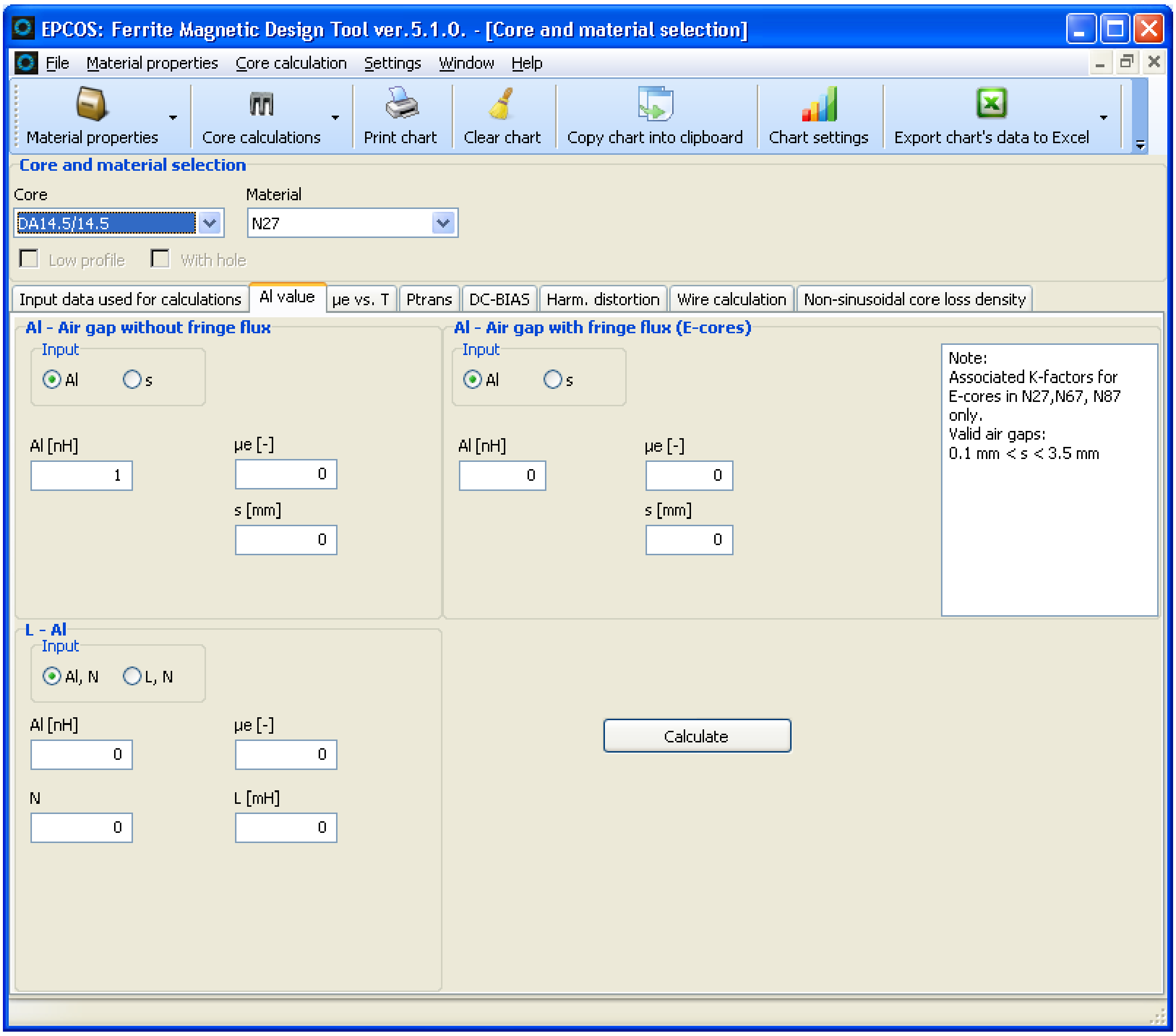

Fig. 4-5 - AL-value

- Select the desired core.
- Specify the core form (optionally: low profile, with hole). *Note:* Please observe that not all combinations are valid (e.g. in low profile, only RM cores are available). Values will not be output if an invalid combination was specified.
- Select the desired material.

- Enter the values for the calculation in the input fields and click the yellow “calculate” button.

The results will be displayed in the associated output fields.

4.5. DC-Bias

For all available TDK power materials and most core shapes, the reversible permeability can be calculated as a function of the DC-current as well as of the DC-field with a given Al value. For this purpose, the temperatures T = 25 °C and T = 100 °C are taken into consideration. With a given number of turns, the reversible inductance and the magnetic energy can additionally be calculated.

4.5.1. Procedure

- Click on the *DC-Bias* button in the main window. The *DC-Bias* window will be opened.

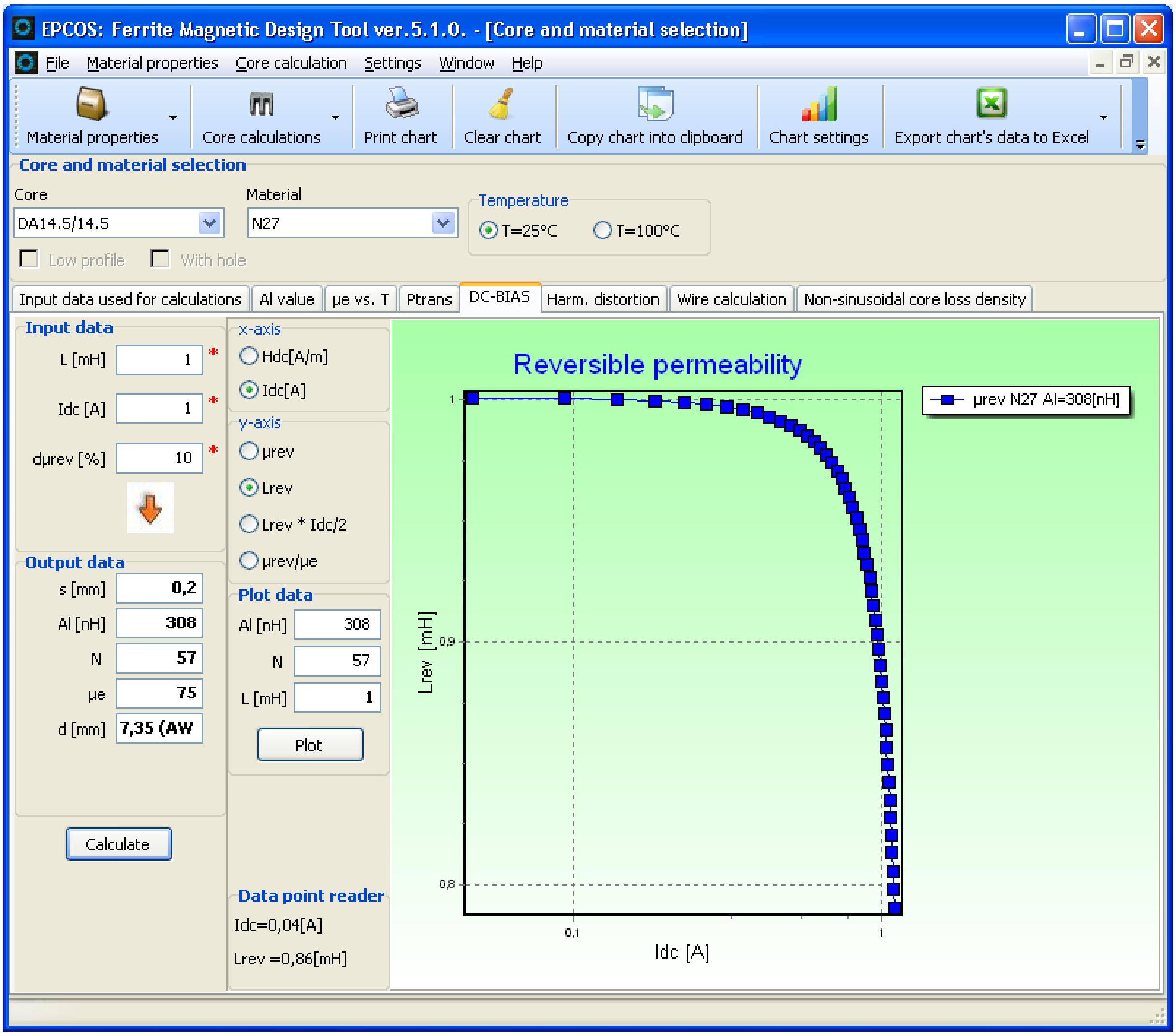

Fig. 4-6 - DC-Bias

- Select the desired core.

- Specify the core form (optionally: low profile, with hole). *Note:* Please observe that not all combinations are valid (e.g. in low profile, only RM cores are available). Values will not be output if an invalid combination was specified.
- Select the desired material.
- Select the desired temperature (T = 25 °C or T = 100 °C).
- Select the measurands that are to be represented on the X- and Y-axes.
- Enter the desired values for the unbiased inductance L in [mH], the DC-current Idc in [A] and the roll-off p in[%] in the corresponding input fields.
- Click the yellow “calculate” button. The calculated values will be displayed in the output fields and a corresponding plot shown.
- If you want to change the Al value and/or number of turns N for new plot data, enter the new values and press the *Return* key.

The new resulting unbiased inductance and the graph will be displayed.

4.5.2. Underlying Formulae 1) :

$$\frac{\mu rev}{\mu i} = 3 \cdot \frac{df(x)}{dx}, \quad \frac{B}{Bs} = \coth x - \frac{1}{x} = f(x)$$

$$\frac{1}{\mu e} = \frac{1}{\mu i} + \frac{s}{le}$$

$$B = \mu a(B) \cdot \mu o \cdot H$$

- Click on measurement points in the curve to view the associated measured values in the *DataPoint Reader*.

4.6. Third Harmonic Distortion

For a given core and a given material, the calculated ratio of the AC-to DC-resistance vs. Frequency for sinusoidal current waveforms can be displayed.

4.6.1. Procedure

- Click on the *Harmonic Distortion* button in the main window.

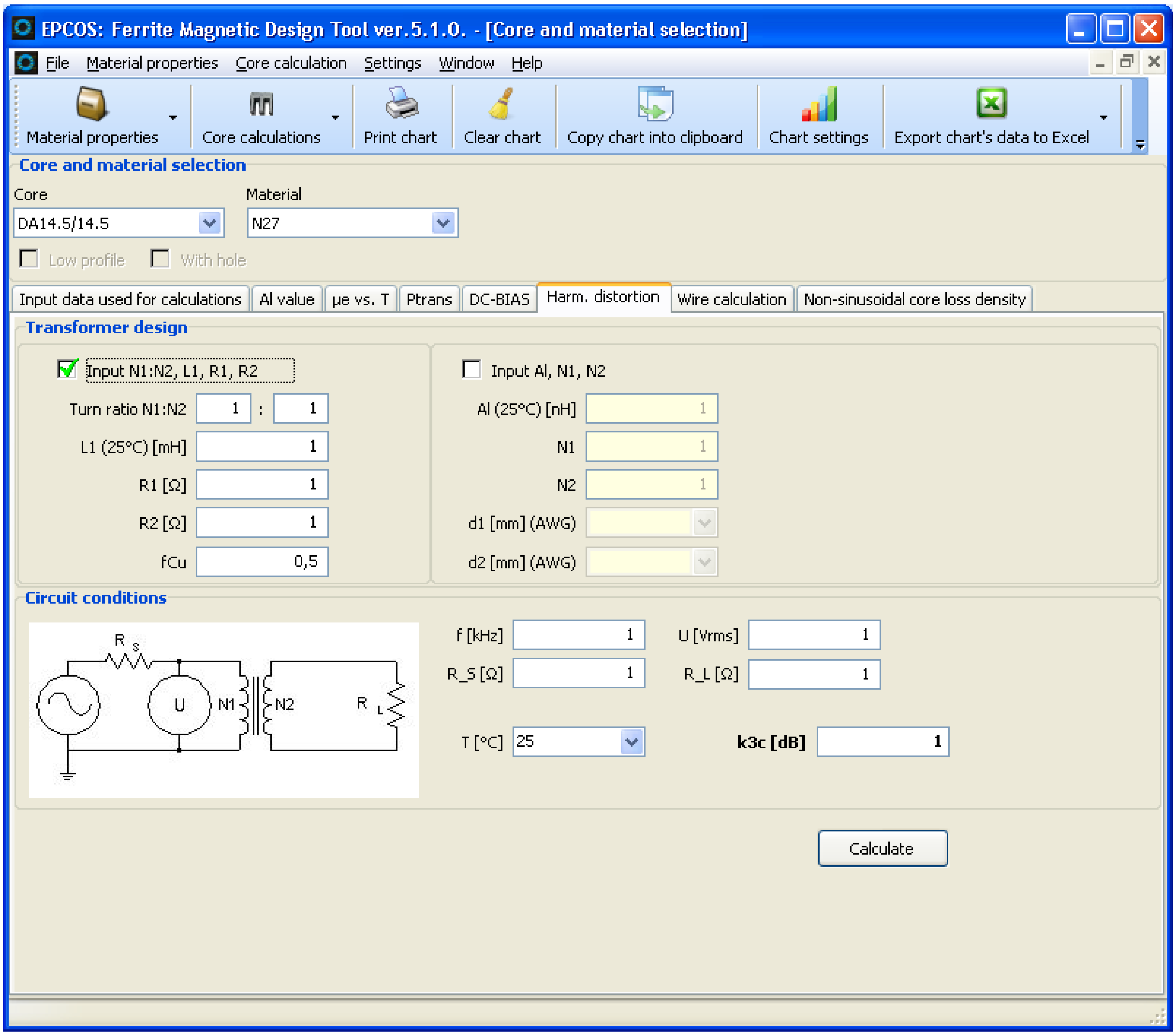

Fig. 4-7 - Third harmonic distortion

- Select the desired core.
- Specify the core form (optionally: low profile, with hole). *Note:* Please observe that not all combinations are valid (e.g. in low profile, only RM cores are available). Values will not be output if an invalid combination was specified.
- Select the desired material.
- Select the desired input option: turns ratio/inductance/resistances or AL-value/number of turns/wire diameter
- Enter the desired values in the corresponding input fields. The calculated values will be displayed in the output fields.

4.6.2. Underlying Formulae:

By using the following equations the third harmonic distortion k3 for the voltage based on Rayleigh´s hysteresis model can be calculated. The in-circuit distortion k3c follows form consideration of the impedance conditions.1) ...

$$k_3 = \frac{0.6}{\mu_0} \cdot \underbrace{\eta_B}_{\text{material}} \cdot \underbrace{\frac{\hat{U}}{\omega}}_{\text{circuit conditions}} \cdot \underbrace{L_k \left[\frac{\rho}{f_{Cu}} \sum_{k=1} \left(N_k / N_1 \right)^2 \frac{1}{R_k} \right]^{3/2}}_{\text{design constraints}} \cdot \underbrace{\underbrace{\frac{\sum_i l_i}{l_e} \cdot \frac{l_e}{A_e^2}}_{\text{core}} \cdot \underbrace{\frac{l_N^{3/2}}{A_N^{3/2}}}_{\text{bobbin}}}_{\text{geometry}}$$

$$k_{3c} = \frac{k_3}{\sqrt{1 + \left[3\omega L_1 \cdot \left(\frac{1}{R_S} + \left(\frac{N_2}{N_1} \right)^2 \cdot \frac{1}{R_L} \right) \right]^2}}$$

4.7. Wire Design

For a given core and a given material, the calculated ratio of the AC-to DC-resistance vs. Frequency for sinusoidal current waveforms can be displayed.

4.7.1. Procedure

- Click on the *Wire Calculation* button in the main window.

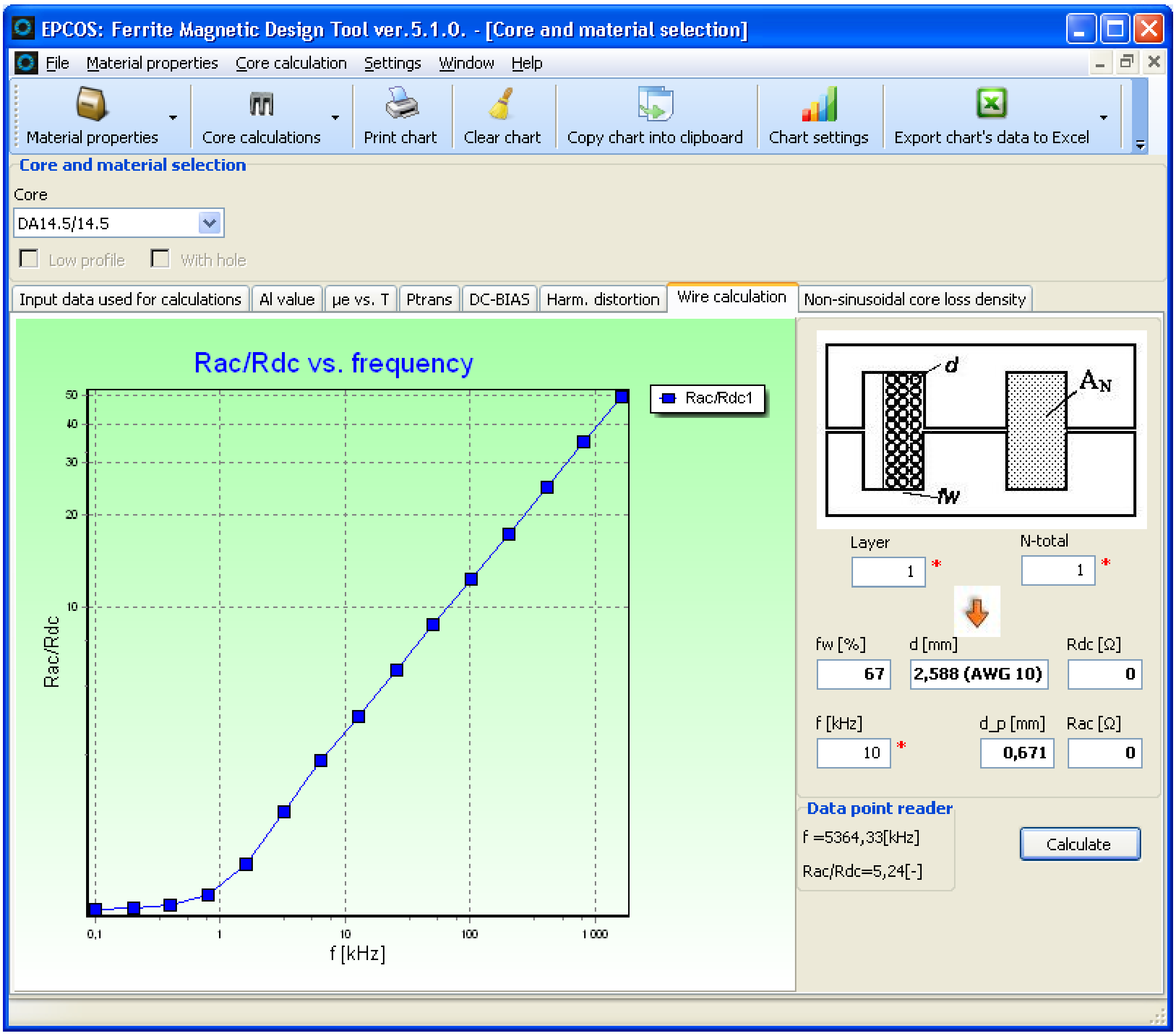

Fig. 4-8 - Wire design

- Select the desired core.
- Specify the core form (optionally: low profile, with hole). *Note:* Please observe that not all combinations are valid (e.g. in low profile, only RM cores are available). Values will not be output if an invalid combination was specified.
- Select the total number of turns
- Select the number of layers
- Click the yellow “calculate” button
- The graph will be displayed. If the window fill factor fw surpasses 100% a warning message will be shown.

4.7.2. Underlying Formulae:

By using the following equations the winding copper losses for sinusoidal current can be estimated. 1) . x stands for the ratio of the wire diameter to the frequency-dependent penetration depth, m stands for number of layers.

$$M = x \frac{\sinh(2x) + \sin(2x)}{\cosh(2x) - \cos(2x)} \, ,$$

$$D = 2x \frac{\sinh(x) - \sin(x)}{\cosh(x) + \cos(x)} \, ,$$

$$F_r = M + \frac{m^2 - 1}{3} D,$$

$$\frac{R_{ac}}{R_{dc}} = F_r$$

5. Graph Control

5.1. Introduction

In the „Edit Chart“ form you can print graphs, insert graphs in other Windows applications via the Clipboard and define the representation of the graph.

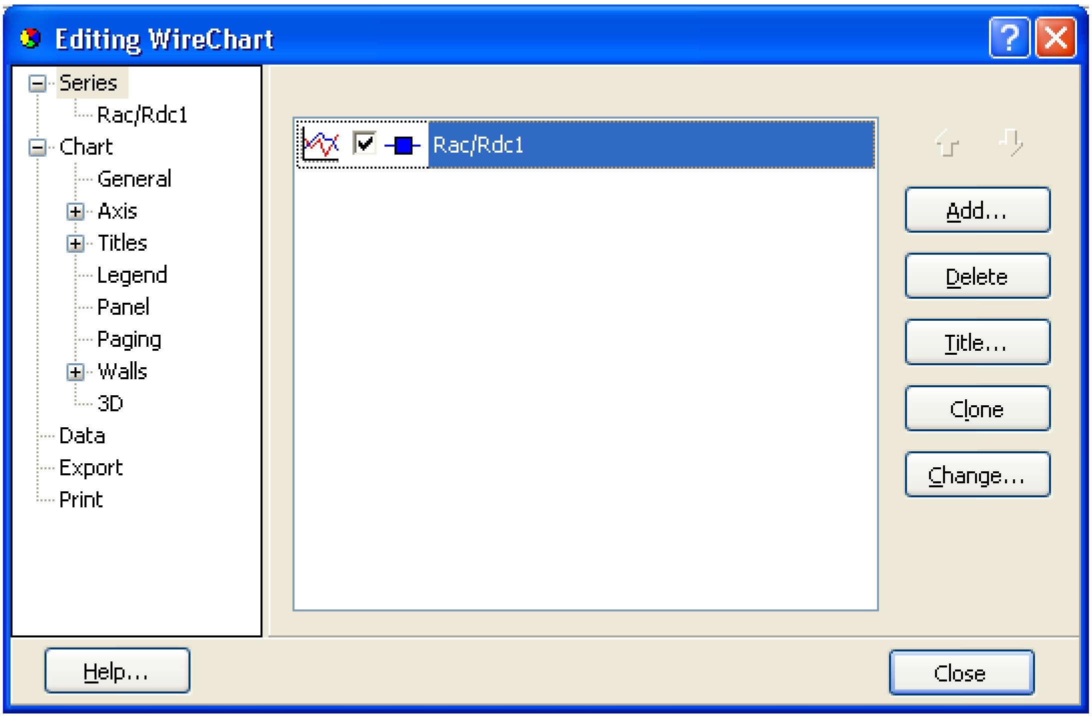

Fig. 5-1 – Edit chart form

5.2. Graph Layout

In the windows for controlling the graph layout, you can define the appearance of your graph. Among other things, you can set the background color, select the axis representation and the desired value range.

Clicking on „Close“ will close the window.

5.3. Printing a graph

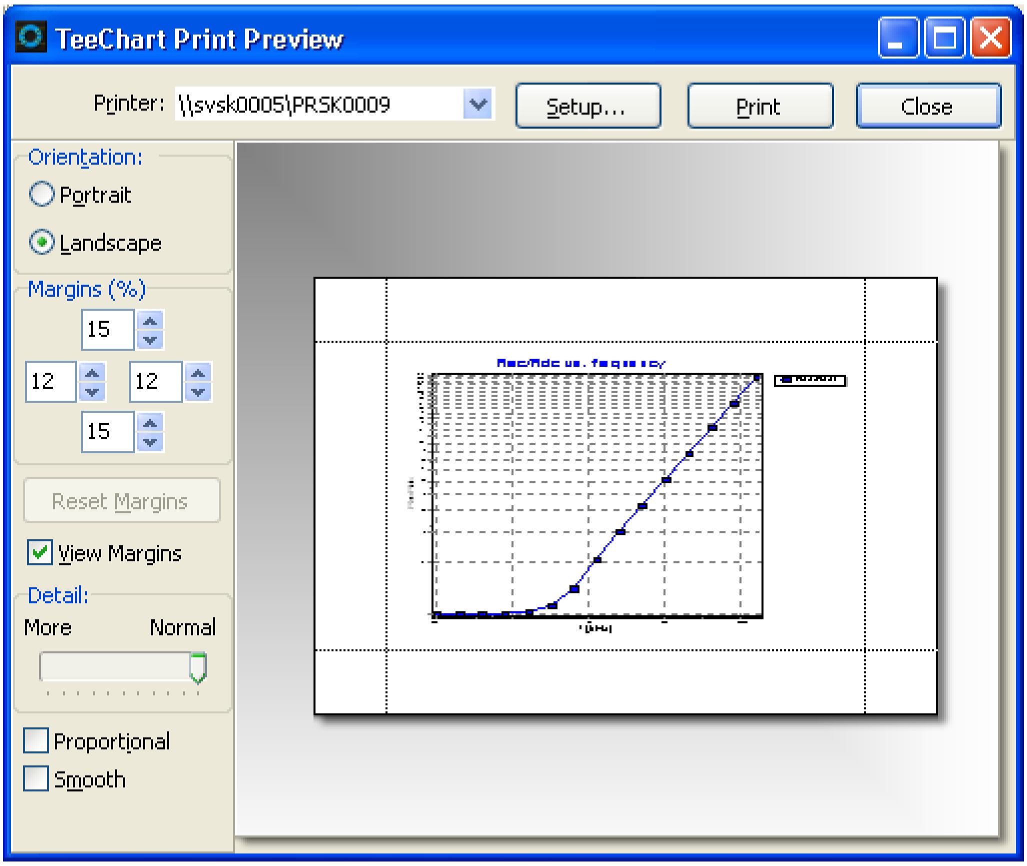

Fig. 5-2 – Printing of graph

- Select printing orientation
- Select printer
- Click on the *Print* button.

The graph will be printed on the selected printer.

5.4. Exporting a graph

You can export the current graph as a graphics file or copy it to the Clipboard to make it available for other Windows applications.

5.4.1. Exporting of graph as file

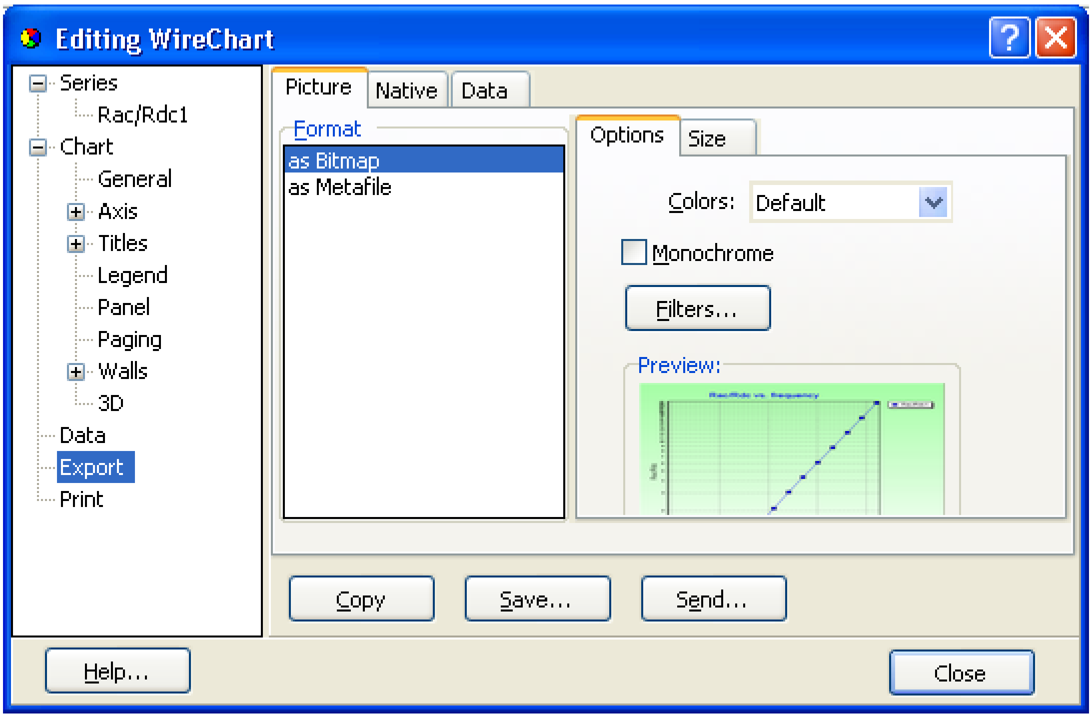

Fig. 5-3 – Graph exporting

- Select the desired data format in the *Export* window area (Metafile or Bitmap).
- Specify the target by button „Save…“
- Click on the *„Save“* button.

The graphics file will be saved.

5.4.2. Copying a graph via the clipboard

Proceed as follows to copy the current graph to the Clipboard to make it available for other Windows applications:

- Select the desired data format in the *Export* window area (Metafile or Bitmap).
- Click on the *Copy* button. The graphics file will be saved.
- Now change to your Windows application (e.g. Word). Position the cursor to the desired insertion point and select *Paste*.

The graph will be inserted in your document.

5.4.3. Exporting data into external file

If you want to export data from chart into external file, use following setup (Fig. 5-4):

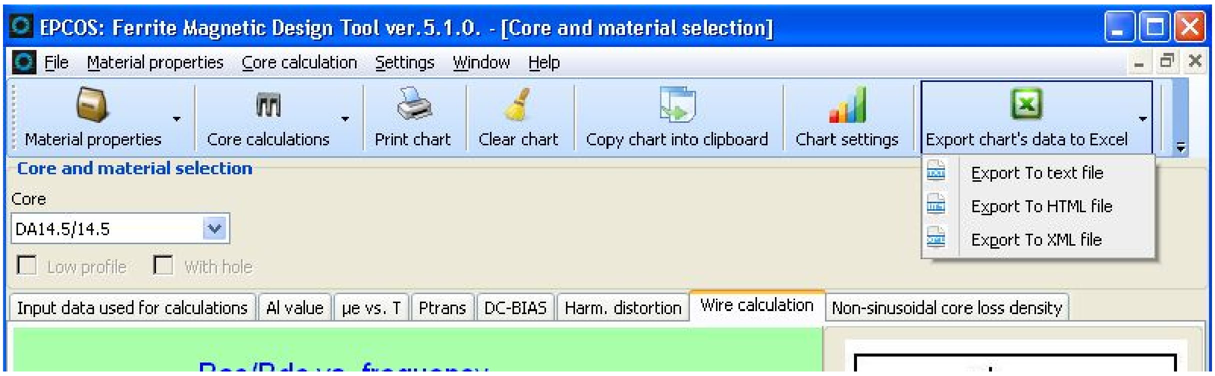

Fig. 5-4 – Data export

If you want to export data into MS Excel, you must click on button "Export chart's data to Excel". You can also export these data into formats "txt", 'html" and "xml". If you ant to export data from chart to these formats, just click on arrow on button "Export chart's data to Excel" and you will see following menu as fig.5-4. Then select appropriate format and click on this item and save data.

6. Settings

If you want to change a font of visual controls, select "Settings – Options". Following form will be displayed – Fig. 6-1.

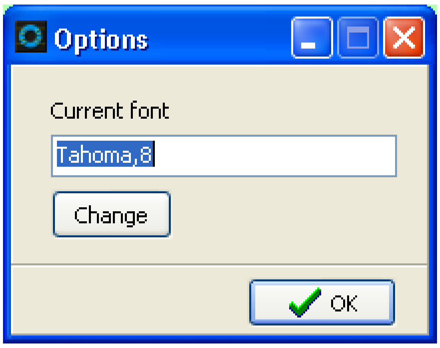

Fig. 6-1 – Options

Click on button "Change" and select desired font. The font will be saved on hard disk and this font will be used during next running of application.

7. Reference List

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