Altair® FluxMotor® 2023

Materials

General user information

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1 MATERIALS OVERVIEW

1.1 Main areas of “Materials”

“Materials” is a dedicated application to create and manage materials.

All materials are distributed into seven families:

- Lamination
- Solid
- Magnet
- Electrical conductor
- Electrical insulator
- Gas
- Liquid

All the above seven families contain some materials individually. When clicking on each family, the corresponding materials are displayed.

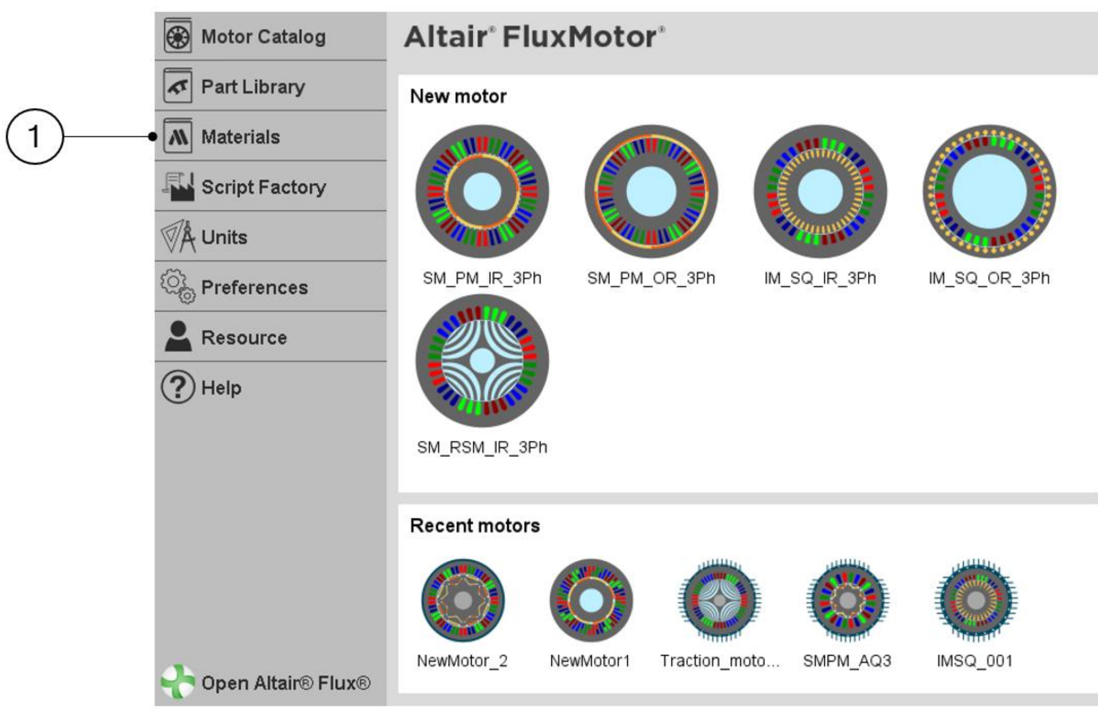
Materials are stocked in databases: A REFERENCE material database is offered. In addition, the users has also the possibility to create their own materials, that will be stored under a material database USER.

1.2 How to get into “Materials”?

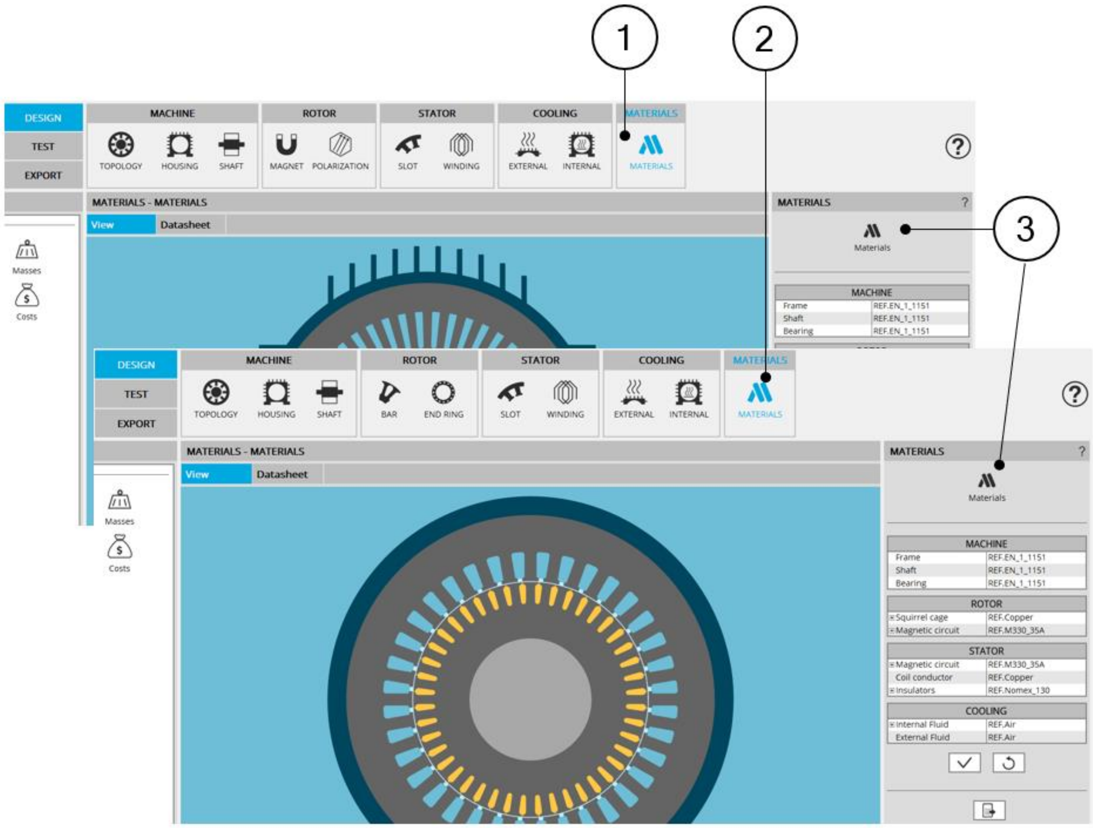
Two ways are possible:

1) From the supervisor, click on “Materials” button.

2) From the Motor Factory DESIGN area, it is possible to check the properties of materials through the STATOR/MATERIALS section, in ROTOR/MATERIALS section or in STATOR/WINDING section.



1	Click on Materials on the left part of the supervisor to open “Materials” application



How to get into “Materials” from Motor Factory?

1	From Motor Factory / DESIGN / MATERIALS section for synchronous machines – Inner and outer rotor
2	From Motor Factory / DESIGN / MATERIALS section for induction machines – Inner and outer rotor
3	In “Materials” environment of Motor Factory, the Material database can be opened by clicking on this button.

1.3 Advice for use

Altair® FluxMotor® is a dedicated to the predesign of electrical motors. The target of Altair® FluxMotor® is to get a quick overview of technical and economic potential of motors.

The motive of the associated material database is to cover the field of needed materials to build a machine.
So, the aim of the material database is not to give perfectly accurate properties of all the specific materials given by the main material suppliers all over the world.

The objective of the material database is to propose the main types of needed materials required for building a motor to have a general overview of motor by using different main kind of materials.

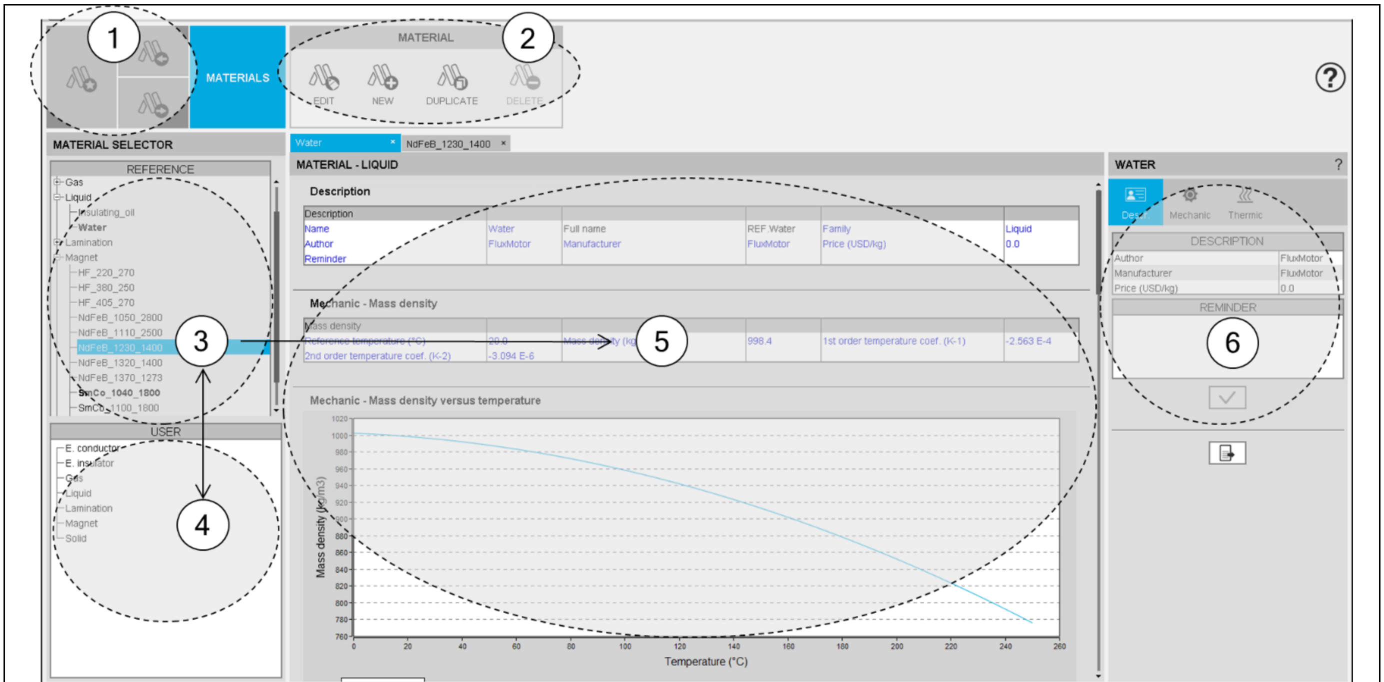
This principle must simply allow visualizing the variation of performance when substituting a material type for another one.

However, the users of FluxMotor® will be able to build their own material database by specifying all the properties needed. Specifying accurate properties of materials remains the responsibility of the user.

2 MANAGE MATERIALS

2.1 Overview

Here are the main areas of the “Materials” application.

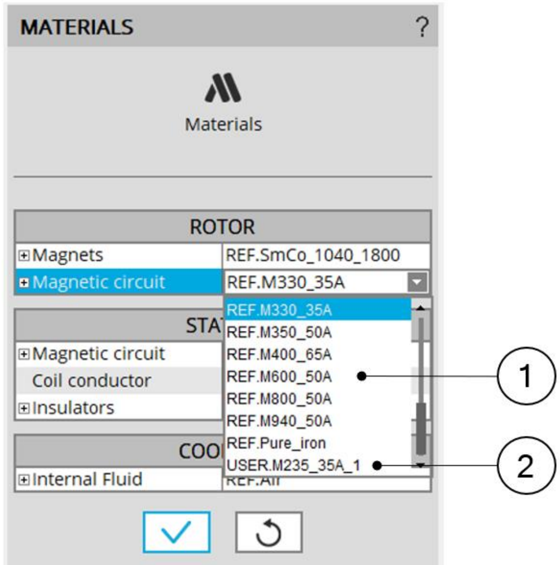


Zones of “Materials” application

Zone 1	Access to the system function: • Assignment of default materials • Export database • Import database See more details on these functions below.
Zone 2	Functions to manage the materials in the selected family: • Edit • New • Duplicate • Delete
Zone 3	Reference material database. In each material family there are some materials which are proposed by FluxMotor® to cover the basic needs.
Zone 4	User material database. One user material database is available. All the materials created by the user are stored in the user database.
Zone 5	Area in which the physical properties of the selected material are displayed.
Zone 6	Area in which the material physical properties are shown. These properties are classified according with its physical domain and the material family. Material properties can be modified only for materials in the USER database. To edit a material in the REFERENCE database it should be copy to USER data base using “duplicate” option.

Note 1: In Motor Factory a material from the reference material database has the following prefix: "REF." Example: REF.M250.50A.

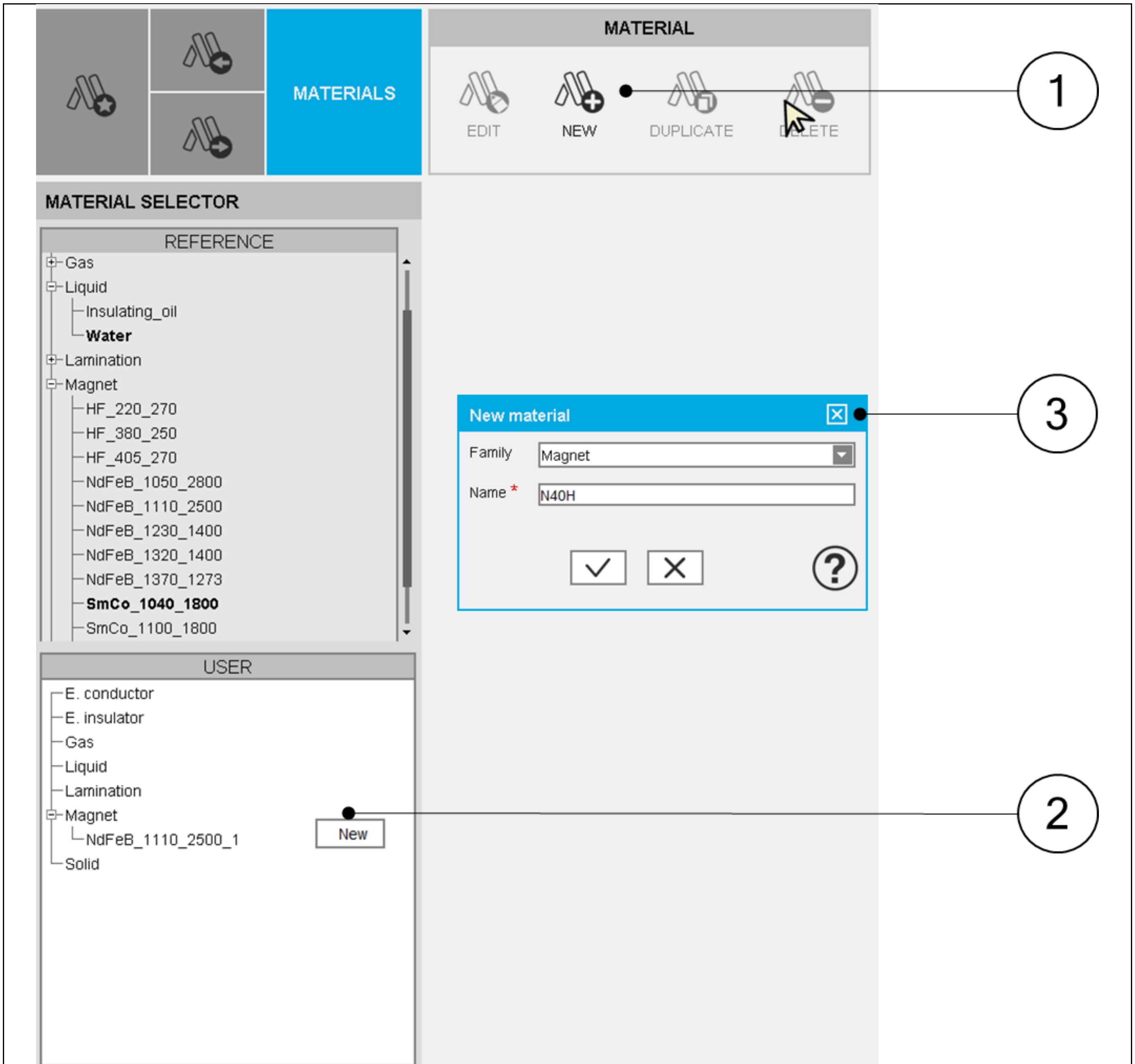
Similarly, a material from the user material database has the following prefix: "USER." Example: USER.M250.50A.



Selection of a material from the Motor Factory	
1	Material stored in the reference material database (Prefix REF.).
2	Material stored in the user material database (Prefix USER.).

2.2 Create a new material

A new material can be created and is stored only in the USER material database.



How to create a new material?	
1	By clicking on the icon "New" in the "Material" menu.
2	By using the right mouse button on one family of the user material database.
3	Select the family and the name of the new material in the dialog box. Family is preselected when material is created using option 2.

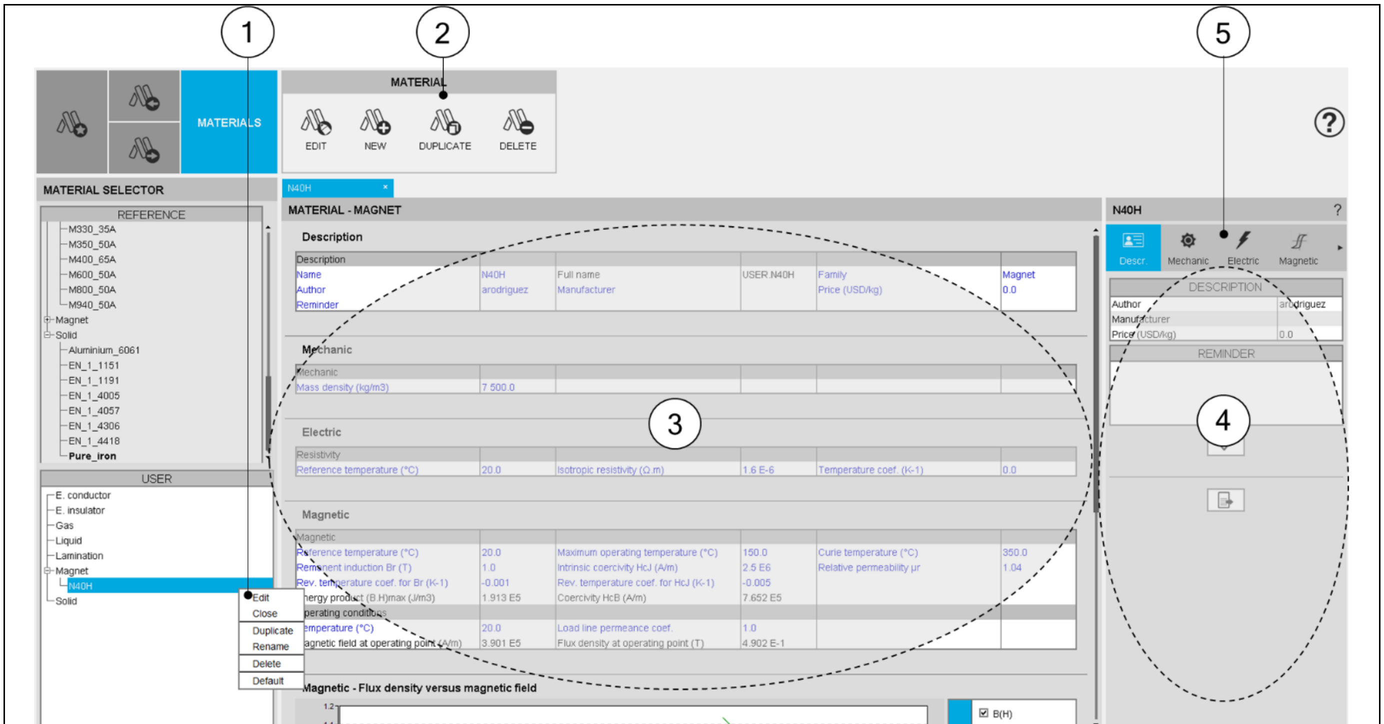
Note : Physical properties of the new created material will have by default values. Edit the material to update them.

2.3 Edit a material

2.3.1 Overview

It is possible to edit a material from the user material database to update its properties. Editing is necessary to introduce the physical properties of a new created material.
Editing a material has two different steps:

- Open the material to display its properties
- Edit the material properties navigating through the different physical domains.

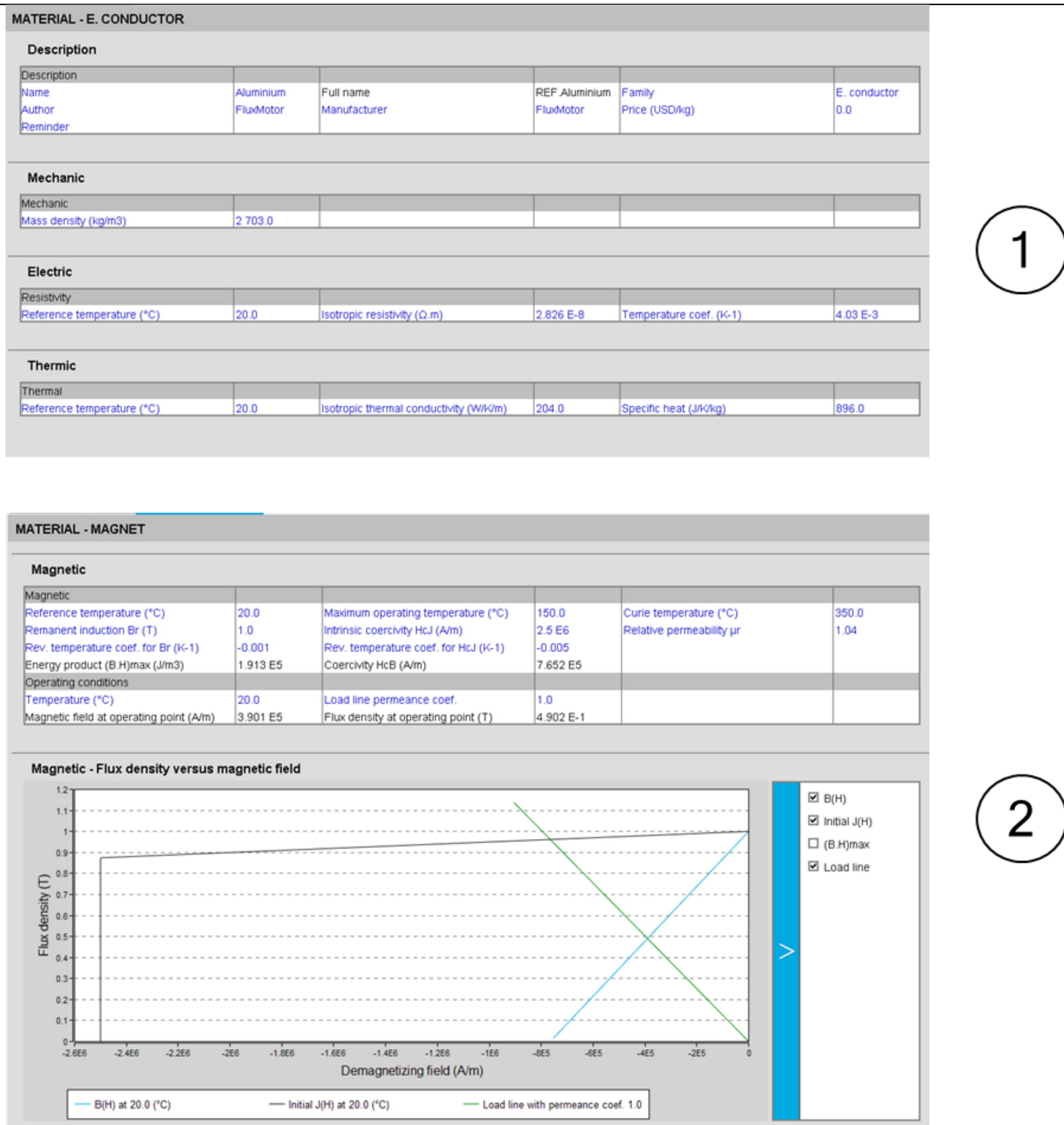


How to edit a material to update properties?	
1	By using the right mouse button on one material of the user material database.
2	By selecting a material and clicking in “Edit” in the “Material” menu.
3	Outputs- Material properties (values and eventually curves) will be displayed.
4	Inputs – The general description of material can be modified in this area (Author, Manufacturer, Price and Reminder) Note that the price is used in Motor Factory to compute the overall cost of the machine (for materials).
5	Use the icons of this menu to select the category. Depending on the material family some of all these categories may be available: • Description • Mechanic • Electric • Magnetic • Iron losses • Thermic • Operating conditions

2.3.2 Outputs

In this area all the physical properties of the material will be shown including the inputs variables, and also the physical properties deduced from the inputs and curves describing the material behavior.

The output information will vary depending on the family of the considered material.

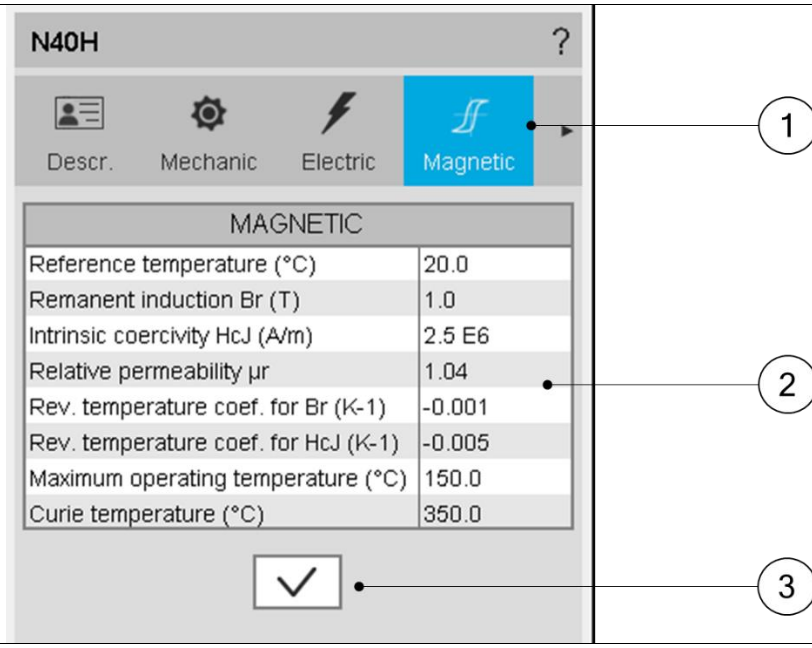


Output area	
1	Example of a material from the family "Electric conductor".
2	Example of a material from the family "Magnet".

2.3.3 Inputs

In this area the properties of the material can be edited if it belongs to the USER database.

To introduce the variables values the user should navigate between the different categories. Categories will vary depending on the family of the edited material.



	Method to define the material properties
1	Select the category.
2	Introduce the desired values.
3	Use the apply button to accept the new values.

2.3.3.1 Lamination inputs

Here are the properties that can be edited in a lamination:

Category	Label	Unit
Description	Author	*
	Manufacturer	*
	Price	USD/kg
	Reminder	*
Mechanic data	Sheet thickness	mm
	Stacking factor	1
	Mass density	kg/m3
	Young modulus	N/m2
	Poisson ratio	1
Magnetic data	Relative permeability (linear BH model)	1
	Saturation magnetic polarization (non-linear BH model)	T
	Initial relative permeability (non-linear BH model)	1
	Knee coefficient (non-linear BH model)	1
Iron Loss	Hysteresis loss coefficient	1
	Exponent of B for the hysteresis losses	1
	Exponent of f for the hysteresis losses	1
	Classical loss coefficient - Sine wave	1
	Exponent for the classical losses	1
	Excess loss coefficient - Sine wave	1
	Exponent of B for the excess losses	1
Thermic data	Reference temperature	°C
	Sheet thermal conductivity at reference conditions	W/K/m
	Insulation thermal conductivity at reference conditions	W/K/m
	Specific heat at reference conditions	J/K/kg
Operating conditions	Frequency	Hz

Note 1: The B(H) curve is defined with an analytical model given in the Advanced section: Create a B(H) curve.

Note 2: A stacking factor is considered to define the B(H) curve to analyze the behavior of the magnetic circuit of the machine.
The user must define the magnetic characteristics of the solid material while the magnetic characteristics of the lamination stack are automatically deduced considering the value of the stacking factor.
See Advanced section: Create a B(H) curve.

Note 3: Electric properties are defined via iron loss model.

Note 4: Iron losses are defined with an analytical model given in Advanced section: Define iron loss parameters.

Note 5: The thermal conductivity “in depth” along the stacking direction: K_d is computed as follows:

S_f	Stacking factor
K_{ins}	Thermal conductivity of the lamination insulation
K_{lam}	Thermal conductivity in the lamination

$$K_d = \frac{K_{ins} \times K_{lam}}{K_{ins} \times S_f + (1 - S_f) \times K_{lam}}$$

Note 6: The thermal conductivity of laminated regions is considered to be constant, whatever is the temperature of the region.

2.3.3.2 Solid data

Here are the properties that can be edited in a solid:

Category	Label	Unit
Description	Author	*
	Manufacturer	*
	Price	USD/kg
	Reminder	*
Mechanic data	Mass density	kg/m3
	Young`s modulus	N/m2
	Poisson's ratio	1
Electrical data	Reference temperature	°C
	Isotropic resistivity at reference conditions	Ohm*m
	Isotropic resistivity temperature coefficient	1/K
Magnetic data	Relative permeability (linear BH model)	1
	Saturation magnetic polarization (non-linear BH model)	T
	Initial relative permeability (non-linear BH model)	1
	Knee coefficient (non-linear BH model)	1
Thermic data	Reference Temperature	°C
	Isotropic thermal conductivity at reference condition	W/K/m
	Specific heat at reference conditions	J/K/Kg

Note 1: The B(H) curve is defined with an analytical model, as described in the Advanced section: Create a B(H) curve.

Note 2: Iron losses are not considered in solid materials.

Note 3: The relation between the electrical resistivity and the temperature is described in Advanced section: "Impact of temperature on physical properties".

Note 4: The thermal conductivity of solid regions is considered to be constant, whatever is the temperature of the region.

2.3.3.3 Magnet data

Here are the properties that can be edited in a magnet:

Category	Label	Unit
Description	Author	*
	Manufacturer	*
	Price	USD/kg
	Reminder	*
Mechanic data	Mass density	kg/m3
Electrical data	Reference temperature	°C
	Isotropic resistivity at reference conditions	Ohm*m
	Isotropic resistivity temperature coefficient	1/K
Magnetic data	Reference temperature	°C
	Remanent flux density at reference conditions Br	T
	Intrinsic coercivity HcJ	A/m
	Relative permeability	1
	Reverse temperature coefficient for Br	1/K
	Reverse temperature coefficient for HcJ	1/K
	Maximum operating temperature	°C
	Curie temperature	°C
Thermic data	Reference Temperature	°C
	Isotropic thermal conductivity at reference condition	W/K/m
	Specific heat at reference conditions	J/K/Kg
Operating conditions	Temperature	°C
	Load line permeance coefficient	1

Note 1: The relations between the remanent flux density, the intrinsic coercivity and the temperature are described in advanced section: "Impact of temperature on physical properties".

Note 2: The thermal conductivity of the magnet regions is considered to be independent of temperature.

2.3.3.4 Electric conductor data

Here are the properties that can be edited in an electrical conductor:

Category	Label	Unit
Description	Author	*
	Manufacturer	*
	Price	USD/kg
	Reminder	*
Mechanic data	Mass density	kg/m3
Electrical data	Reference temperature	°C
	Isotropic resistivity at reference conditions	Ohm*m
	Isotropic resistivity temperature coefficient	1/K
Thermic data	Reference Temperature	°C
	Isotropic thermal conductivity at reference condition	W/K/m
	Specific heat at reference conditions	J/K/Kg

Note 1: Non-magnetic behavior.
Note 2: The relation between the electrical resistivity and the temperature is described in Advanced section: "Impact of temperature on physical properties".
Note 3: Thermic variables (thermal conductivity and specific heat) are considered to be constants and independents of temperature. Reference temperature is given, but its value does not affect the thermal model of the conductor.

2.3.3.5 Electric insulator data

Here are the properties that can be edited in an electrical insulator:

Category	Label	Unit
Description	Author	*
	Manufacturer	*
	Price	USD/kg
	Reminder	*
Mechanic data	Mass density	kg/m3
Thermic data	Reference Temperature	°C
	Isotropic thermal conductivity at reference condition	W/K/m
	Specific heat at reference conditions	J/K/Kg

Note 1: Non-electrical and non-magnetic behavior.
Note 2: Thermic variables (thermal conductivity and specific heat) are considered to be constants and independent of temperature. Reference temperature is given but its value does not affect the thermal model of the insulator.

2.3.3.6 Gas data

Here are the properties that can be edited in a gas:

Category	Label	Unit
Description	Author	*
	Manufacturer	*
	Price	USD/kg
	Reminder	*
Mechanic data	Reference pressure	Pa
	Mass density reference temperature	°C
	Mass density at reference conditions	kg/m3
	Mass density first order temperature coefficient	1/K
	Mass density second order temperature coefficient	$1/K^2$
	Dynamic viscosity reference temperature	°C
	Dynamic viscosity at reference conditions	kg/m/s
	Dynamic viscosity first order temperature coefficient	1/K
	Dynamic viscosity second order temperature coefficient	$1/K^2$
Thermic data	Thermal conductivity reference temperature	°C
	Thermal conductivity at reference conditions	W/K/m
	Thermal conductivity first order temperature coefficient	1/K
	Thermal conductivity second order temperature coefficient	$1/K^2$
	Specific heat reference temperature	°C
	Specific heat at reference conditions	J/K/kg
	Specific heat first order temperature coefficient	1/K
	Specific heat second order temperature coefficient	$1/K^2$
Operating conditions	Pressure	Pa

Note: Gas is considered to have no electrical and no magnetic properties.

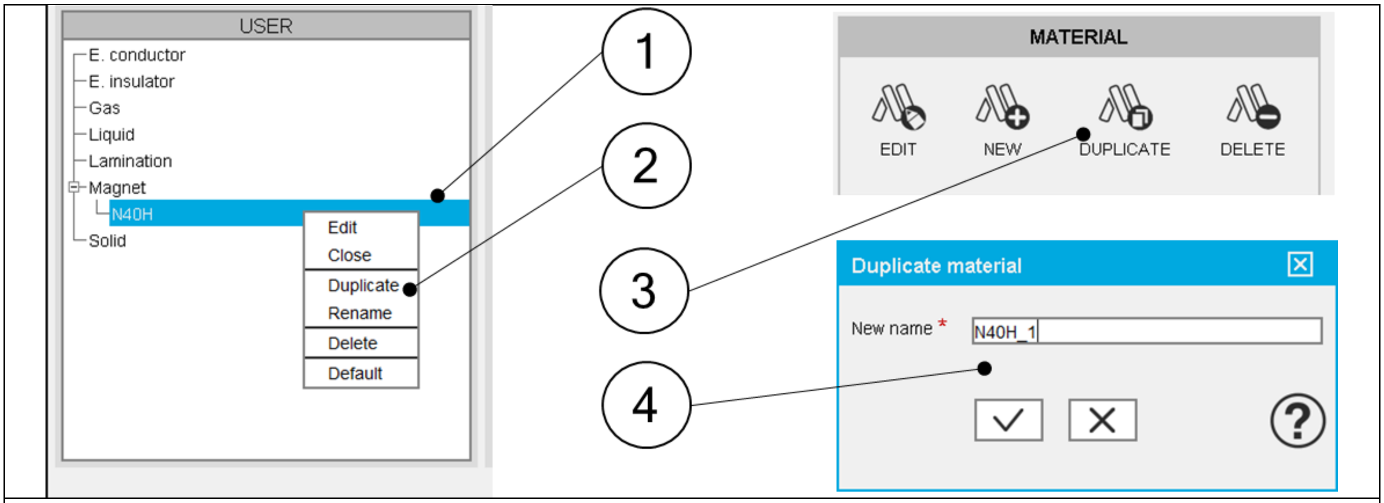
2.3.3.7 Liquid data

Here are the properties that can be edited in a liquid:

Category	Label	Unit
Description	Author	*
	Manufacturer	*
	Price	USD/kg
	Reminder	*
	Mass density reference temperature	°C
	Mass density at reference conditions	kg/m3
	Mass density first order temperature coefficient	1/K
	Mass density second order temperature coefficient	$1/K^2$
	Dynamic viscosity reference temperature	°C
	Dynamic viscosity at reference conditions	kg/m/s
	Dynamic viscosity first order temperature coefficient	1/K
	Dynamic viscosity second order temperature coefficient	$1/K^2$
Thermic data	Thermal conductivity reference temperature	°C
	Thermal conductivity at reference conditions	W/K/m
	Thermal conductivity first order temperature coefficient	1/K
	Thermal conductivity second order temperature coefficient	$1/K^2$
	Specific heat reference temperature	°C
	Specific heat at reference conditions	J/K/kg
	Specific heat first order temperature coefficient	1/K
	Specific heat second order temperature coefficient	$1/K^2$
	Thermal expansion reference temperature	°C
	Thermal expansion at reference conditions	1/K
	Thermal expansion first order temperature coefficient	1/K
	Thermal expansion second order temperature coefficient	$1/K^2$

2.4 Duplicate a material

All the materials can be duplicated either from the reference material database or from the user material database.
For any origin of the material (reference or user material database), the new material resulting from the duplication will be stored in the user material database.
Duplicate a material allows creating a new material from one already existing with another name. It is possible to modify (by editing it) the corresponding properties to personalize it.

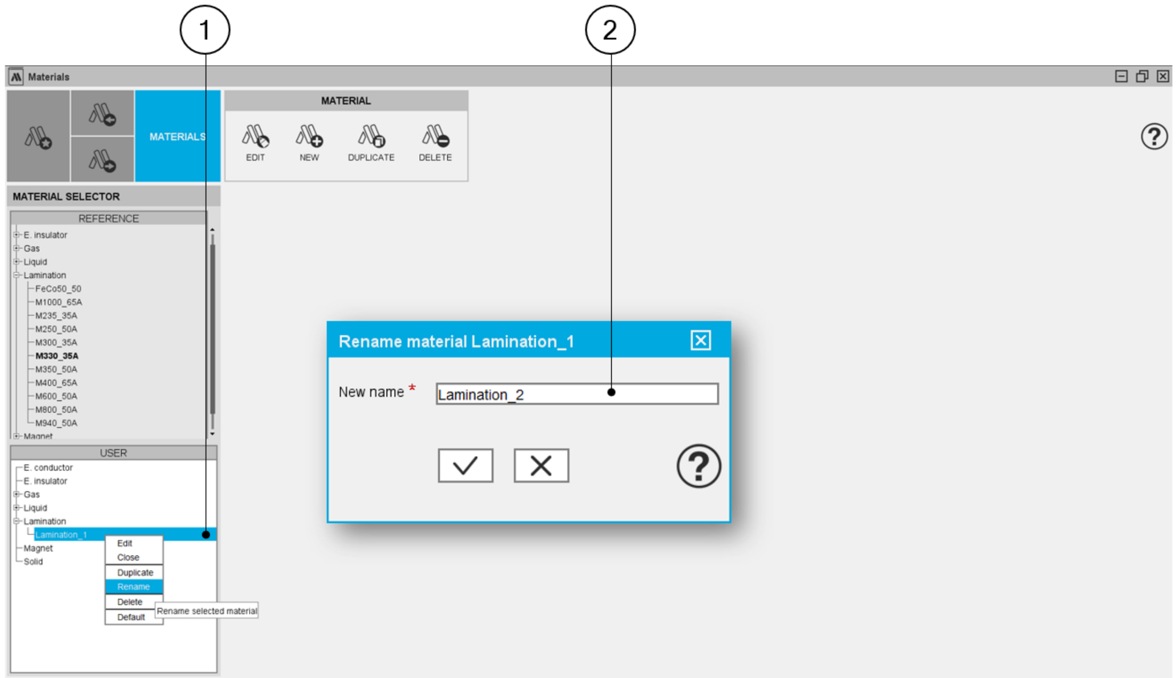


How to duplicate a material?

1	In any case, the material to be duplicated must be selected
2	The first way to duplicate a material consists of using the right mouse button to expand the corresponding menu and then clicking on the function Duplicate.
3	The second way to duplicate a material consists of clicking on the “Duplicate” button in the area, where several functions are located at bottom part of the user material database to manage the materials.
4	Select the new name of the new material in the dedicated dialog box and accept the duplication.

2.5 Rename a material

All the materials stored in the “User material database” can be renamed. The name of materials stored in the reference material database cannot be renamed. If needed, they can be duplicated as illustrated in the previous section.



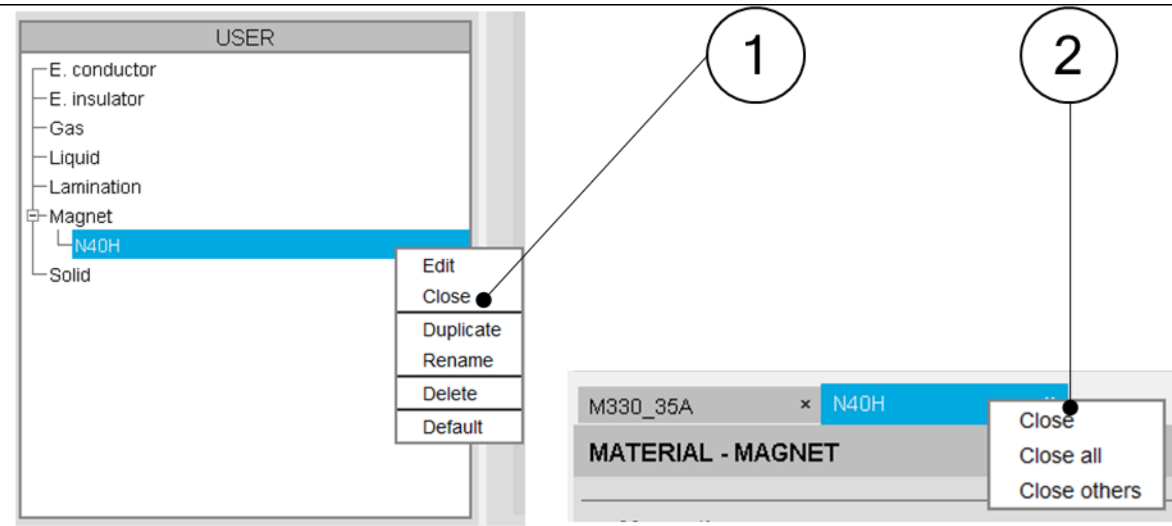
How to rename a material?	
1	Click on the material label you want to rename (click on the right mouse button)
2	Give a new name in the dedicated dialog box. Note: The new name must not already exist in the material database, even for another type of material.

2.6 Close a material

“Close a material” consists of removing the tabs of the material from the display area (output area). Several materials can be edited at the same time, therefore editing a new material does not automatically close the others.

Two ways are possible to close a material. These are shown below.

Note: The properties of the materials are hidden, but the material still exists in the material database.



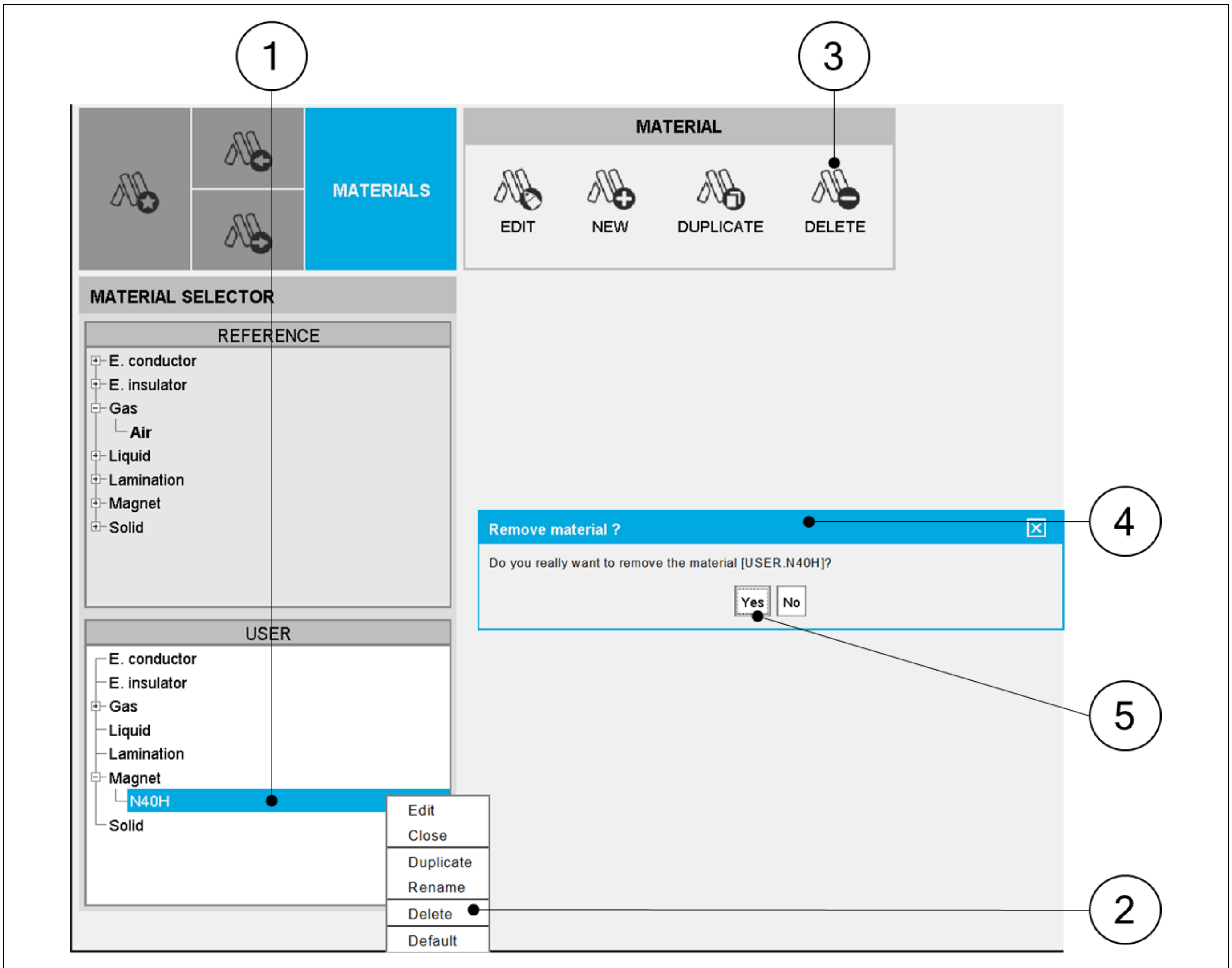
How to hide the material properties?	
1	By selecting the material, clicking the right mouse button, and selecting the close option.
2	By selecting the material tab (above the display area), clicking the right mouse button and selecting one of the proposed options: close only the selected material, close all the materials or close all the materials excepting the selected one.

2.7 Delete a material

"Delete a material" implies that it is removed from the material database.

Only materials from the user material database can be deleted.

Note: While deleting a material used in the design of an existing motor, the name of this material and all the corresponding physical properties are kept in the data of the motor. These are kept if the material is not changed in the motor. If the material is replaced by another one, the former material (removed from the material database) won't be usable anymore.

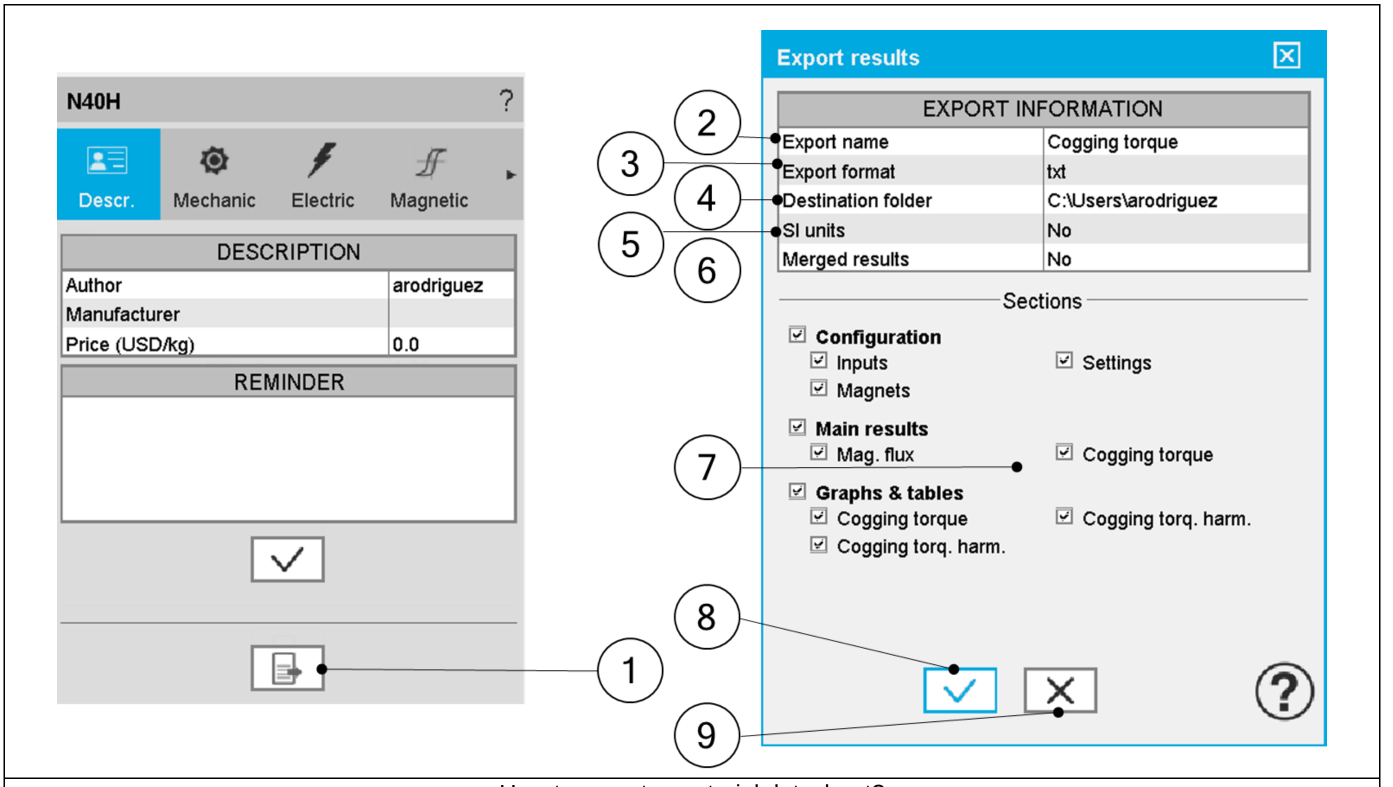


How to delete a material?	
1	Select the name of the material to be deleted.
2	The first way to delete a material consists of using the right mouse button to expand the corresponding menu and clicking on the function "Delete".
3	The second way to delete a material consists of clicking on the "Delete" button in the area where several functions are located at bottom part of the user material database to manage the materials.
4	A dedicated dialog box allows finalizing the deletion of the selected material. Note: Several materials can be selected to be deleted.
5	The deletion of the material is achieved when clicking on "Yes". Obviously, it is possible to cancel the deletion by clicking on "No".

2.8 Export a material datasheet

It is possible to export the datasheet of a material which is being displayed.

Material properties are classified in different categories depending on its family. It is possible to choose one or several of these categories to be exported.



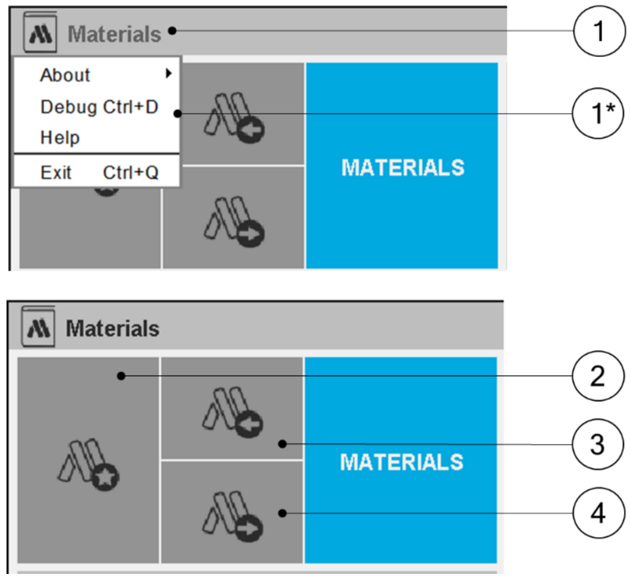
How to export a material datasheet?	
1	By using the dedicated button inside the input area, a dedicated dialog box gets opened
2	Name of the exporting text file
3	Choice for exporting data into *.txt or *.xls files
4	Folder in which the provided file will be stored
5	System of units for numerical data can be given using SI Units (Units based on International System of Units). If the answer is “No”, the default units used in FluxMotor will be considered
6	Merged results means the results are written in one single text file. When the answer is no, a text file is provided for each category of result.
7	Visualization of all categories of the material properties. Categories must be checked for adding them to the text files.
8	Button to apply inputs, closing the panel and opening the folder in which the generated text files are stored
9	Button to cancel action and close the panel

3 SYSTEM FUNCTIONS

3.1 Overview

The main system functions are directly accessible from the “Materials” application area.
Expanding the menu in the left top part of “Materials” is also available.

Here is the presentation of these functions:

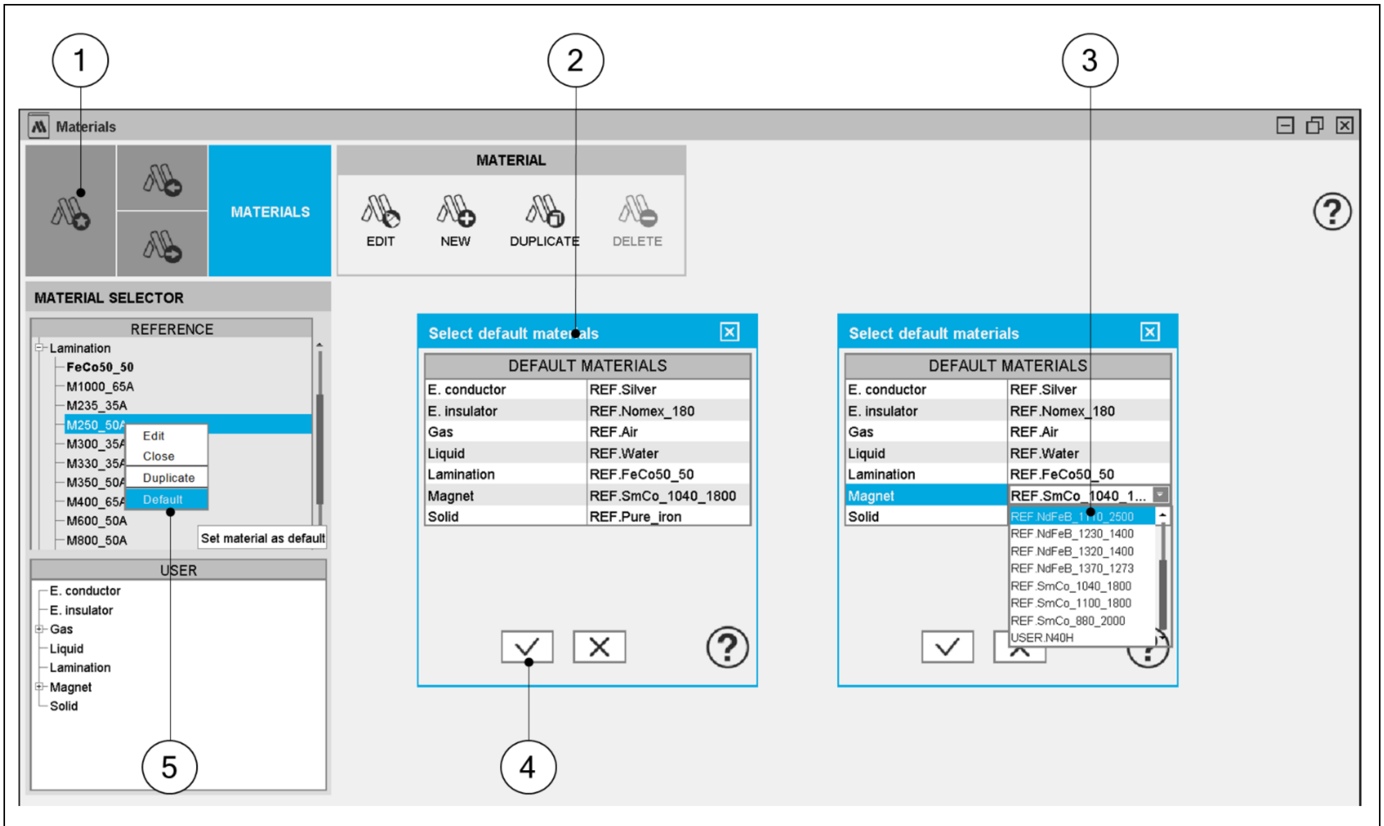


1	Access to the top menu of “Materials” area to reach functions like (1*): • About • Debug mode • Help • Exit
2	Select default materials ready to be used in Motor Factory via Quick building access.
3	Import materials databases
4	Export materials databases

3.2 Define default materials

The aim of this option is to declare a default material for each material family.
Each time a user creates a new machine in Motor Factory, these default materials will be automatically chosen.

Here is the way to define default materials:

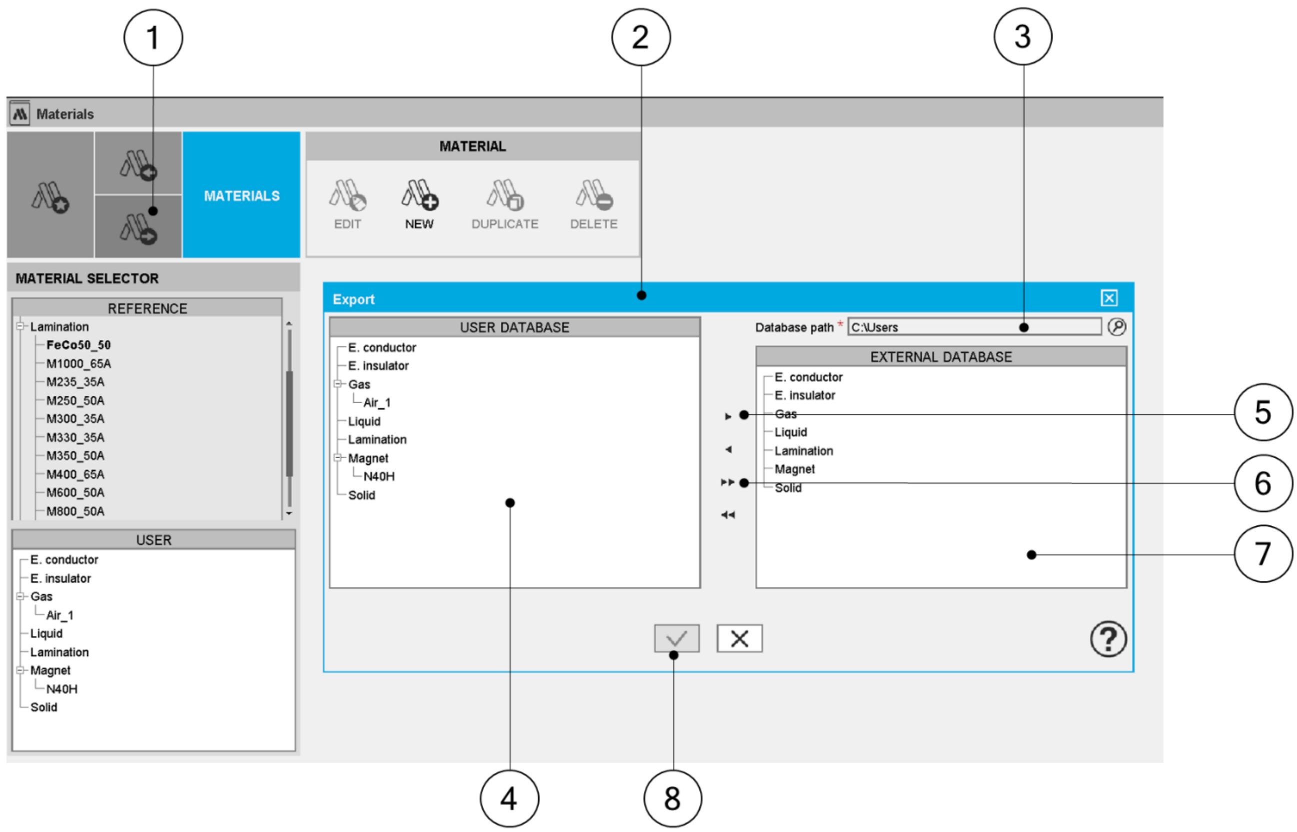


1	Main button to open the dialog box allows declaring the default materials.
2	Dialog box allows choosing one default material for each material family.
3	For each material family, expanding the menu allows choosing among all the possible materials stored in the material database (REFERENCE as well as USER material database).
4	The choices of default materials are achieved when clicking on the “Validate” button. It is also possible to cancel the choice.
5	Additionally, it is possible to choose any material as the default material of its family by clicking the right mouse button on it and selecting the “Default” option.

3.3 Export materials databases

It is possible to export the materials databases from user material database and share it with the other users.

Here is the way to export materials:

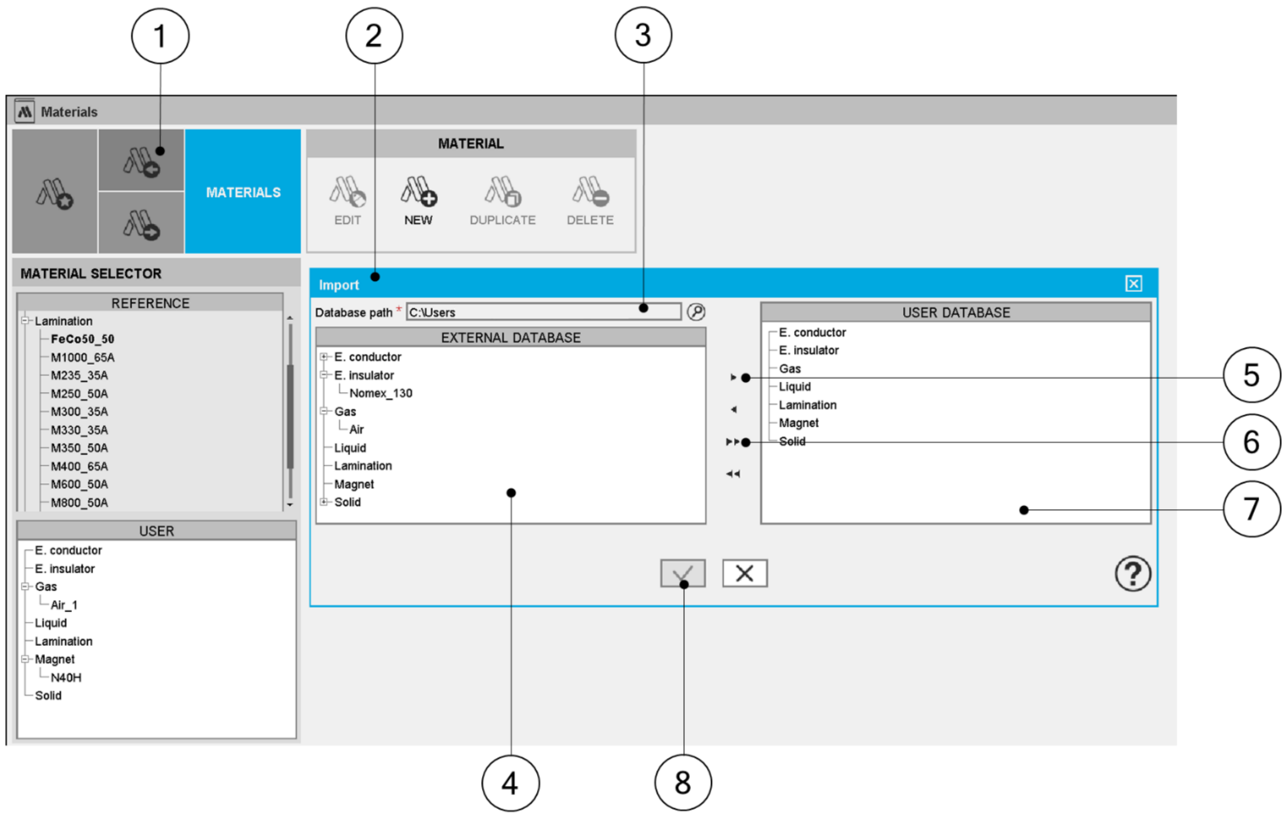


1	Main button to open the dialog box allows exporting materials.
2	Dialog box allows exporting materials from each material family. Note: Only materials from user material database can be exported.
3	Select the path where the exported materials will be stored. Note: This selection is mandatory to continue the process of exporting.
4	Select the materials to be exported in each family. This will confirm the exported database.
5	Choose to export the materials one by one.
6	Choose to export all the materials at the same time.
7	Visualize the materials which are already selected to be exported.
8	Exporting selected materials is achieved when clicking on the Export button. Moreover, it is also possible to cancel the process of exporting.

3.4 Import materials

It is possible to import materials from external material database built by another user of FluxMotor®. All the imported materials will be stored in the user material database.

Here is the way to import materials:

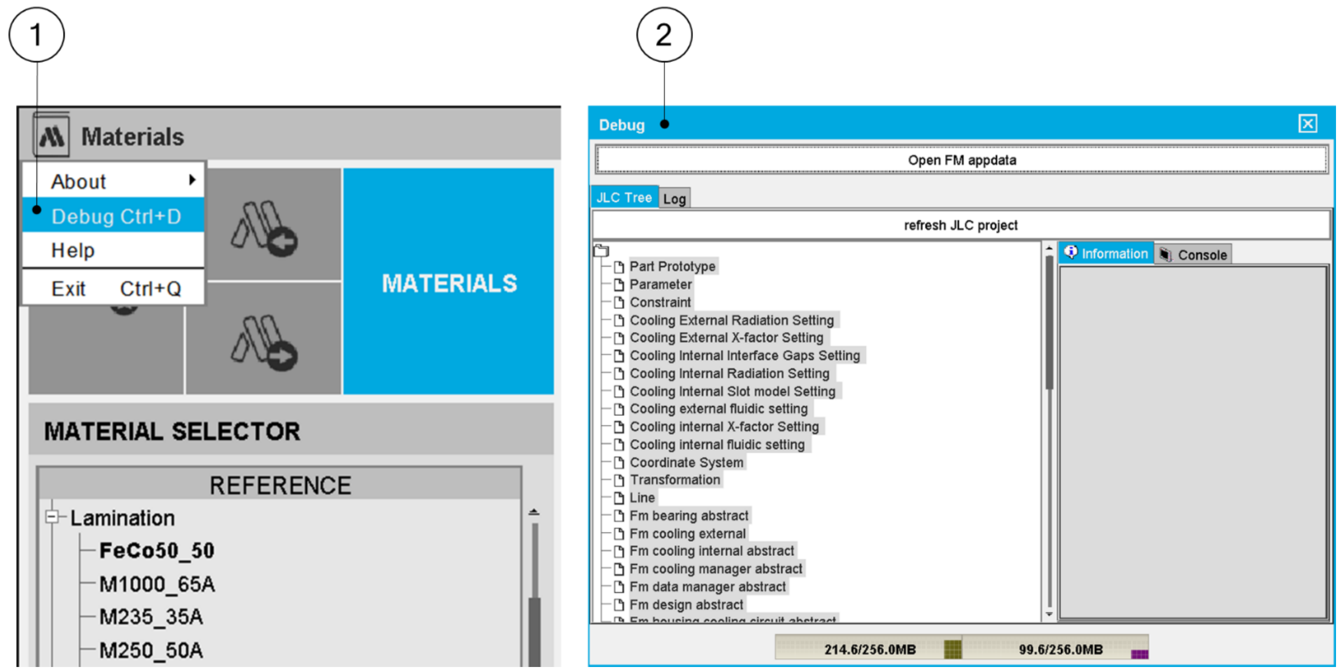


1	Main button to open the dialog box allows importing materials.
2	Dialog box shows importing materials from each material family. Note: Imported materials will be stored in user material database.
3	Select the path from which the materials must be imported. Note: This selection is mandatory to continue the process of exporting.
4	Select the materials to be imported from each family.
5	Choose to import the materials one by one.
6	Choose to import all the materials at the same time.
7	Displaying of the materials that are chosen for import (after exporting).
8	Importing selected materials is achieved by clicking on the Import button. Moreover, it is also possible to cancel the process of importing.

3.5 General functions

3.5.1 Debug mode function

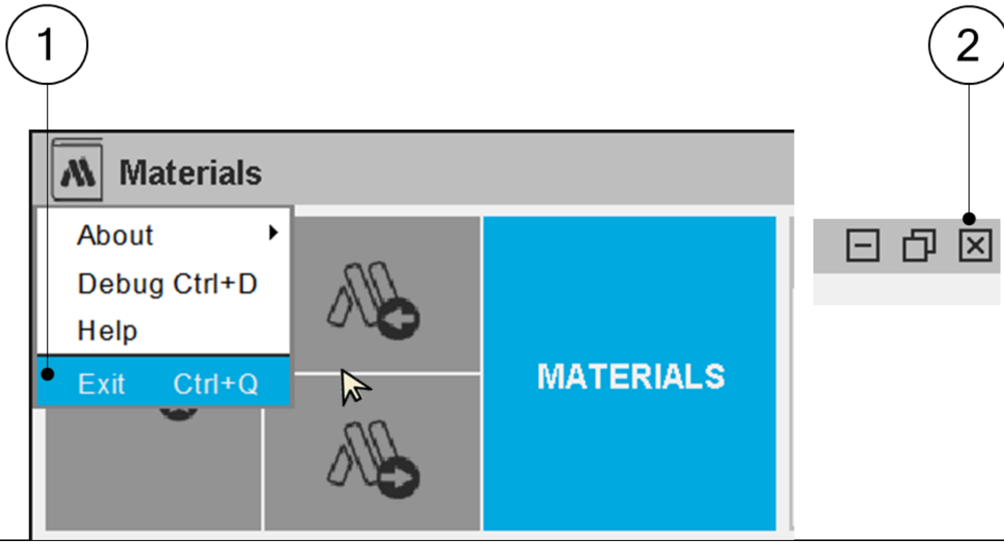
The Debug mode function is dedicated for solving the problem in the “Materials” application.
In case of trouble, instructions will be given by the FluxMotor® support team to use this function.



Mode debug	
1	Access to “Debug mode” from the menu in the top of the “Materials” application.
2	Dialog box corresponding to the “Debug mode” function.
*	Access to the “Debug mode” is possible by using the shortcut CTRL-D, defined in the user FluxMotor® preferences. For more information, refer to the chapter “User’s Preferences”.

3.5.2 Exit

Closing “Materials” application is possible



	Exit – Close “Materials” application
1	Close “Materials” application from the top menu of “Materials” application.
☒	Close “Materials” application by using the following icon on the right top part of the “Materials” application panel. Note: Close “Materials” application by using the shortcut CTRL-Q defined in the user FluxMotor® preferences. For more information, refer to the chapter “User’s Preferences”.

4 ADVANCED

4.1 Define a B(H) curve

4.1.1 Create a B(H) curve – Main principles

The model consists of a combination of a straight line and a curve. A coefficient allows the adjustment of the knee shape for better approximation of the experimental curve.

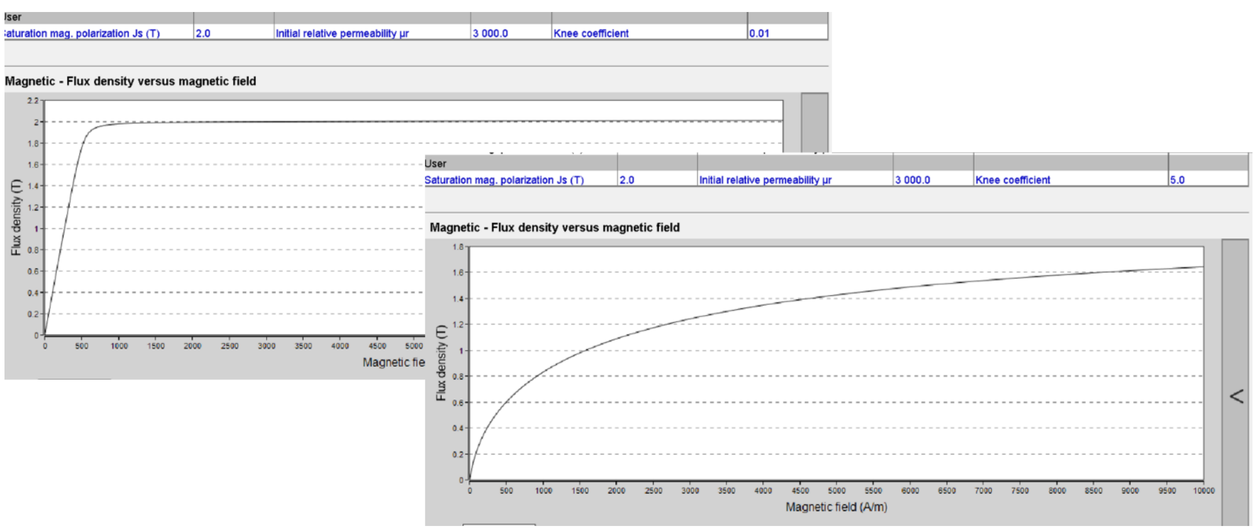
The corresponding mathematical formula is written as follows:

$$B(H) = \mu_0 \times H + J_S \times \frac{H_a + 1 - \sqrt{(H_a + 1)^2 - 4 \times H_a \times (1 - a))}}{2 \times (1 - a)}$$

with $H_a = \mu_0 \times H \times \frac{\mu_r - 1}{J_S}$

$\mu_0 = 4 \times \pi \times 10^{-7}$	Permeability of vacuum.
μ_r	Relative permeability of the material
H	Magnetic field (A/m).
J_S	Magnetic polarization at saturation (T).
a	Knee coefficient of the curve $(a > 0 \quad and \quad a \neq 1)$. The smaller coefficient will give the sharper knee point.

The impact of the knee coefficient "a" on the shape of the B(H) curve is illustrated in the below figure.



Shape of B(H) curve with the function of knee coefficient.
Left knee coefficient = 0.01. Right knee coefficient = 5

4.1.2 Create a B(H) curve – Process

4.1.2.1 Overview

A linear or a non-linear B(H) curve is considered.

In the first case, only the constant value of the relative permeability must be given by the user.

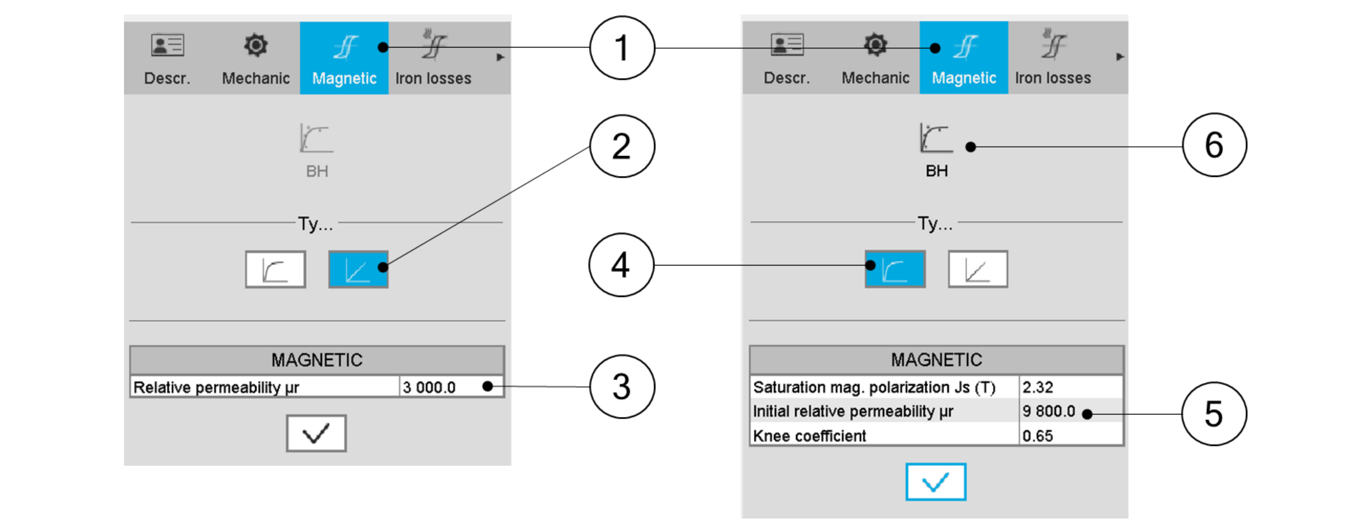
If a lamination is considered, the relative permeability of the lamination stack is automatically deduced.
If a non-linear B(H) curve is considered, these three main parameters of the magnetic characteristics must be defined:

- The magnetic polarization at saturation J_S
- The magnetic permeability (μ_r)
- And the knee coefficient a

If a lamination is considered, the corresponding magnetic characteristic is automatically deduced.

4.1.2.2 Define a B(H) curve from user input parameters

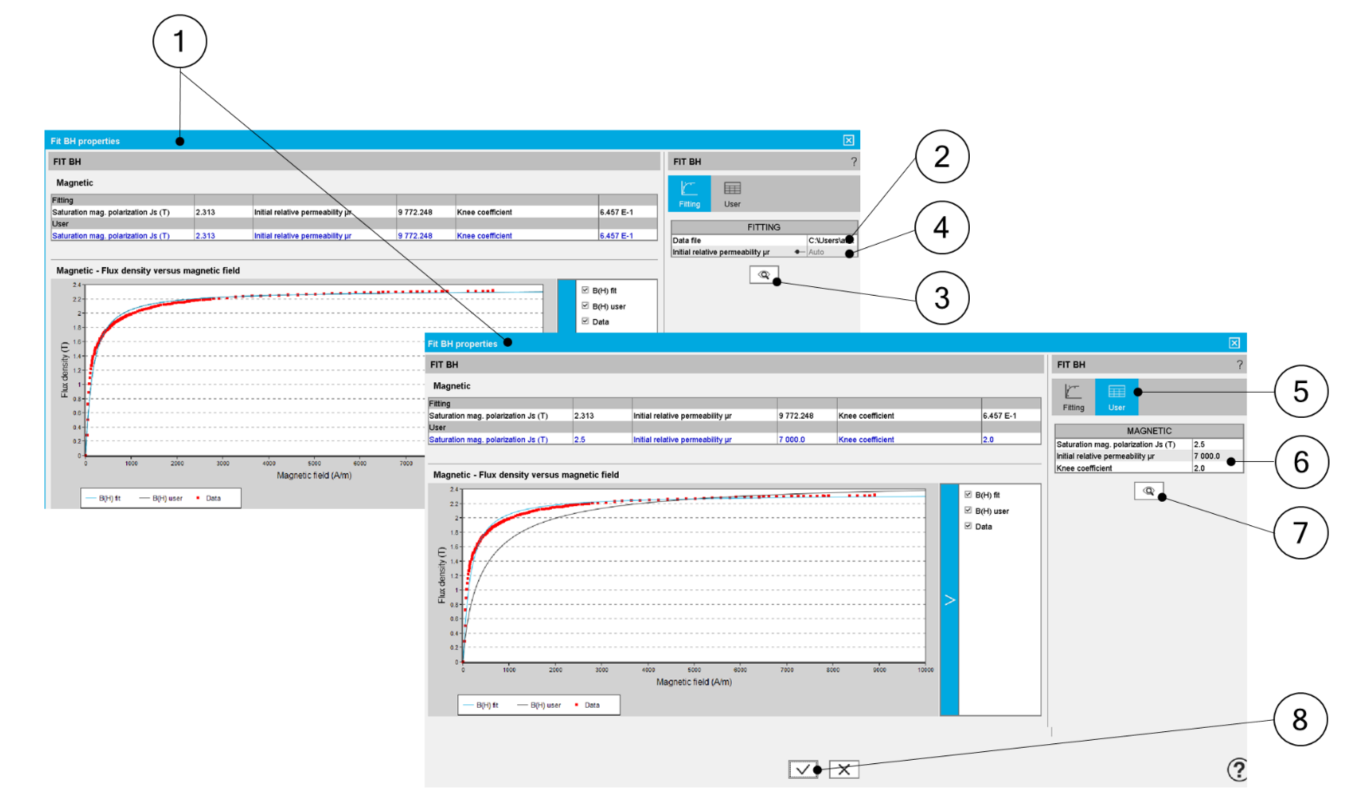
Here is the process to define the B(H) curve from the "Materials" application. In this example, it is considered that the user knows exactly the coefficients to be set.



Characterization of the B(H) curve	
1	When editing the properties of an existing material (lamination and solid families), a category is dedicated to the magnetic data. Hence, clicking on the "Magnetic" one can define the B(H) curve.
2	In the example above, the linear B(H) characteristic of a lamination is considered
3	Only the relative permeability of the corresponding solid material is given. The resulting relative permeability of the lamination stack is automatically deduced (considering the stacking factor mentioned in the mechanical data).
4	In another example, the non-linear B(H) characteristic of a lamination is considered.
5	The three main parameters of the magnetic characteristic that must be given are: • The magnetic polarization at saturation (J_S) • The magnetic permeability (μ_r) • And the knee coefficient a The resulting magnetic characteristics of the lamination stack is automatically deduced (considering the stacking factor mentioned in the mechanical data).
6	Another method is possible to define the non-linear B(H) curve of a material. If the user has measurement or computation points representing the B(H) curve to model, it is possible to import these data to define the corresponding characteristics. This consists of importing a B(H) curve via an Excel file and identifying the three parameters J_S, μ_r and knee coefficient with an optimization process. Click on the icon "Fit" to run this process (only available for non-linear model).

4.1.2.3 Define a B(H) curve from experimental data

Here is the process to define the characteristics of the B(H) curve from the importation of series of points representing the B(H) curve listed in an Excel file.



Identification of the B(H) curve characteristics	
1	Dialog box allowing the characterization of the B(H) curve imported from an Excel file
2	Path where Excel file to be imported is stored. See an example of Excel file below.
3	Accept the import of the Excel file data. When importing an Excel file, points representing the B(H) curve are listed. An optimization process automatically computes and displays the corresponding characteristics Js, µr and a. At the same time three curves are displayed: Red points are the imported points (listed in the Excel file) Blue curve is the resulting curve computed by the optimization process. This corresponds to the computed characteristics and displayed just after the computation. The black curve shows modifications induced if the characteristics Js, µr and a are changed by the user.
4	In this field, two choices are available: • The automatic mode (Auto): The fitting process is entirely automatic for defining the input parameters for the B(H) curve. • The setting of the relative permeability: In that case µr is imposed by the user. HENCE, the optimization process is run by considering only two variables Js and a.
5	The user can adjust one or all the three main characteristics of the B(H) curve: Js, µr and a. To do so user tab must be selected by clicking on its icon. The resulting modification is directly displayed on the graph below.
6	Adjust the three variables to get a new user curve.
7	Accept the user values modification by clicking this button.
8	The last values of JS, µr and a, written in the “user” input fields are validated when the user clicks on this button. It is possible to cancel the creation of the B(H) curve model. In this case, the previous values defined before opening this dialog box are reset.

Example of an Excel file to define the B-H curves parameters.

	A	B	C	D
1				
2		**BH curve**		
3		**Label**	Magnetic field	Magnetic flux density / Vector
4		**Units**	A/m	T
5		**Values**	0,00E+00	0,00E+00
6			3,03E+01	2,88E-01
7			4,22E+01	5,06E-01
8			5,25E+01	7,19E-01
9			6,52E+01	8,86E-01
10			7,65E+01	1,01E+00
11			8,79E+01	1,09E+00
12			9,97E+01	1,16E+00
13			1,13E+02	1,22E+00
14			1,25E+02	1,26E+00
15			1,36E+02	1,30E+00
16			1,45E+02	1,33E+00
17			1,56E+02	1,37E+00
18			1,69E+02	1,39E+00
19			1,82E+02	1,42E+00
20			1,93E+02	1,45E+00
21			2,03E+02	1,47E+00
22			2,15E+02	1,49E+00
23			2,27E+02	1,51E+00
24			2,42E+02	1,53E+00
25			2,54E+02	1,55E+00
26			2,65E+02	1,57E+00
27			2,75E+02	1,58E+00
28			2,88E+02	1,58E+00
29			3,00E+02	1,61E+00

Example of an Excel file to define the B(H) curve parameters

4.2 Define iron loss parameters

4.2.1 Iron losses model - Main principles

The mathematical formula used in FluxMotor® to compute the iron losses is:

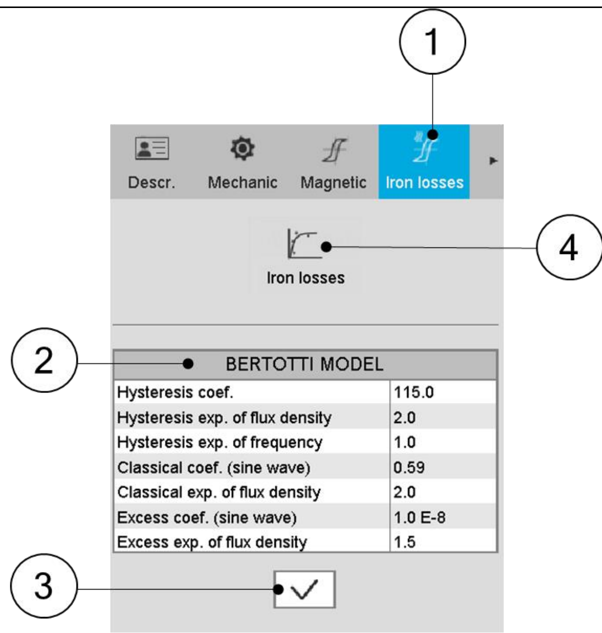
$$P = k_h \times B_{pk}^{\alpha_h} \times f^{\beta_h} + k_c \times \left(B_{pk} \times f\right)^{\alpha_c} + k_e \times \left(B_{pk} \times f\right)^{\alpha_e}$$

Note: Iron loss model is only used for lamination.

Label	Definition
k_h	Hysteresis loss coefficient.
α_h	Exponent of B for the hysteresis losses.
β_h	Exponent of f for the hysteresis losses.
k_c x k_{ac}	Classical loss coefficient – Sine wave.
k_c	Classical loss coefficient – Any wave. Automatically computed from the sine wave value – The field is an output.
α_c	Exponent of B and f for the classical losses.
K_e x k_{ae}	Excess loss coefficient – Sine wave.
k_e	Excess loss coefficient – Any wave Automatically computed from the sine wave value – This field is an output.
α_e	Exponent of B and f for the excess losses.

Note: The formula above is not homogeneous with the considered units.
Indeed, it represents a correspondence between the flux density associated with the frequency and the resulting iron loss amount.
The coefficients listed above are completely independent of units.
In FluxMotor®, P represents the amount of iron losses per cubic meter. This quantity is computed by considering B in Tesla and f in Hertz.
The coefficients are always defined by considering these reference units.
The user can use other units for defining the iron losses or flux density. For example, in FluxMotor® the corresponding quantities are transformed to come back to original units (Tesla, Hz and W/m3).

When editing the properties of a material, a category is dedicated to the iron losses, as can be seen below.



Definition of iron loss coefficients	
1	Category dedicated to iron losses.
2	Parameters defining the iron losses according to the model described above (Bertotti model).
3	Click “ok” button to validate the inputs
4	Click in the fitting icon in order to get an iron losses model from measured data.

4.2.2 How to define iron loss parameters?

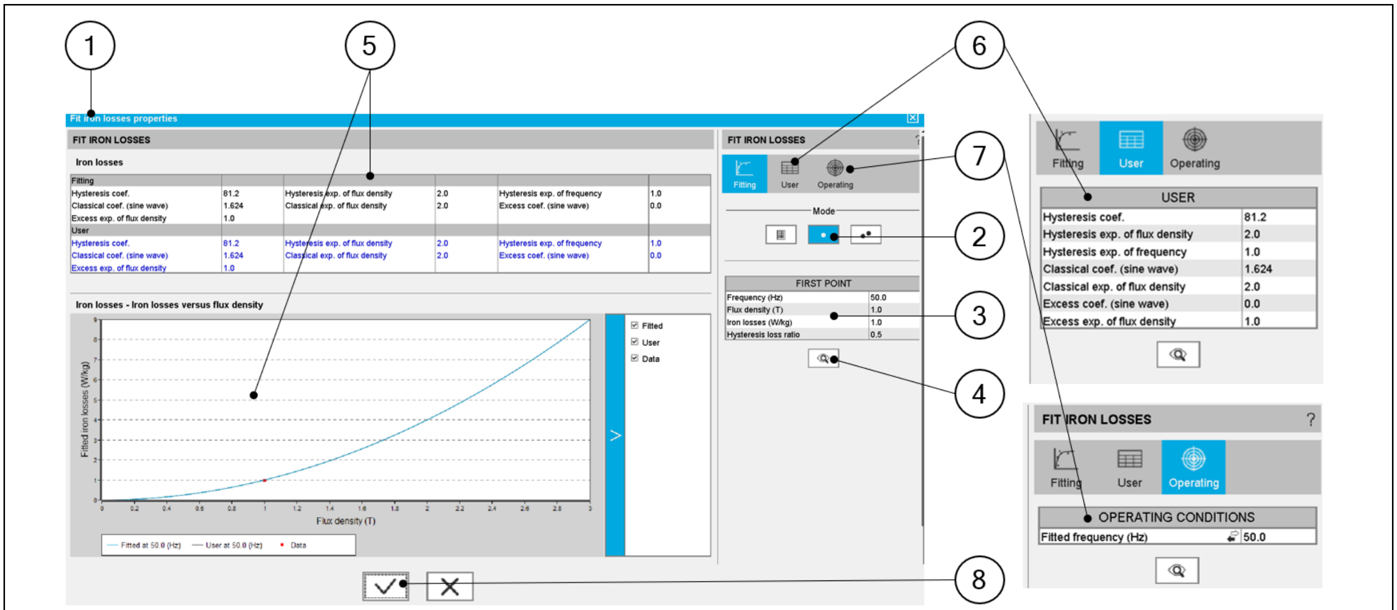
4.2.2.1 Overview

Three main methods are provided to help the users in finding the relevant values for consideration of the iron loss parameters. The choice of the method depends on the data that the user has for the lamination to consider.

Three cases are considered:

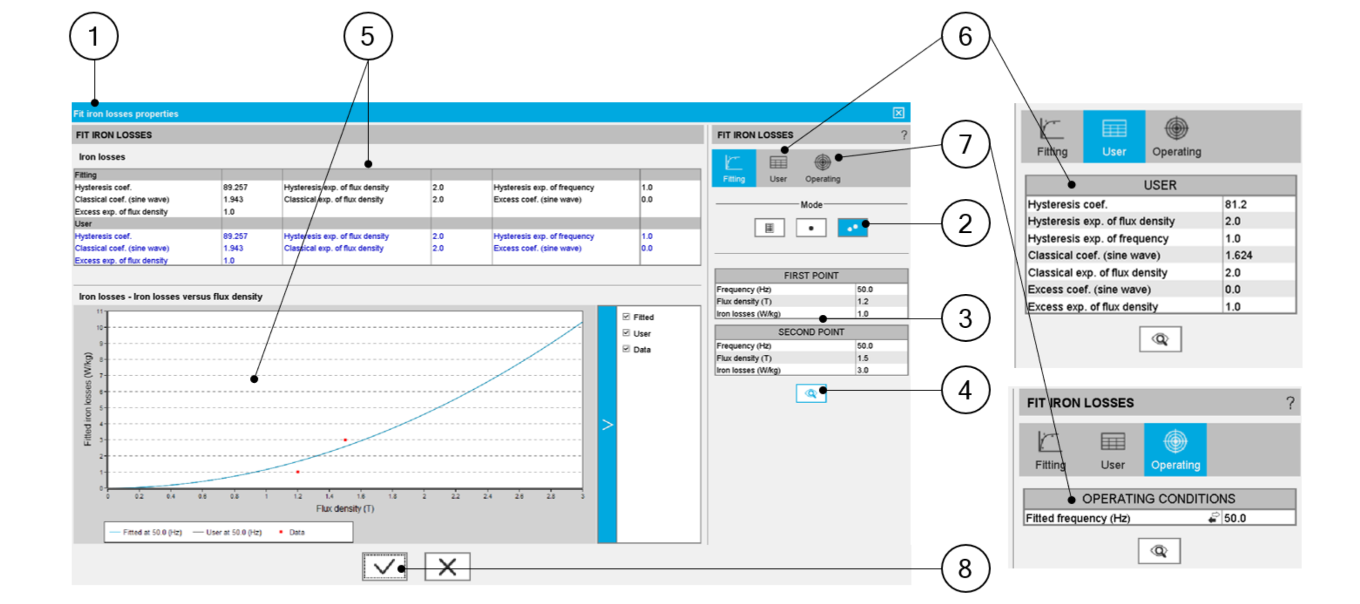
- One measurement point is characterized: Amount of iron losses corresponding to the values (frequency, flux density)
- Two measurement points are characterized: Amount of iron losses corresponding to the values (frequency, flux density)
- Several curves of iron losses in function of flux density for different values of frequency which corresponds to a map of Iron losses in f - B plane (where f= frequency and B=flux density)

4.2.2.2 Case 1: From one measurement point



Definition of iron loss coefficients – from one measurement point	
1	Dialog box dedicated to fit the iron loss parameters. Located in the “iron losses” category when visualizing or editing the material properties.
2	Choice of the method to find iron loss parameters (1 point in this example).
3	Measurement characteristics: • Frequency, • Magnetic flux density • Iron losses (amount of iron losses) • Hysteresis loss ratio. Note: Hysteresis loss ratio is the ratio between the hysteresis losses and the total amount of iron losses.
4	When input parameters characterizing the measurement point are defined, click the button Fit to run the optimization process. This process computes the set of iron loss parameters that allow targeting the considered measurement point.
5	The iron loss input parameters are deduced and displayed in the result table and the corresponding curve, Losses versus B (magnetic flux density) are displayed.
6	The user can adjust one or all the parameters of the iron losses model. To do so user tab must be selected by clicking on its icon. The resulting modification is directly displayed in the output area.
7	It is possible to select a frequency to visualize the behavior of the resulting iron loss curve. To do so, use the “Operating” tab. Note: If the chosen frequency is not one of those used for the fitting (from the user inputs), the measurement points (in red) will not be displayed.
8	Validation of iron loss parameters is achieved by clicking on this button. Moreover, it is also possible to cancel the computation of iron loss parameters.

4.2.2.3 Case 2: From two measurement points



Definition of iron loss coefficients – from two measurement points	
1	Dialog box dedicated to fit the iron loss parameters. Located in the “iron losses” category when visualizing or editing the material properties.
2	Choice of the method to find iron loss parameters (2 points in this example).
3	Measurement characteristics to give for each measurement point: • Frequency (It is highly recommended to take 2 different frequencies as boundaries of the working area) • Induction (magnetic flux density B) • Iron losses (amount of iron losses)
4	When input parameters characterizing the two measurement points are defined, click on the Fit button to run the optimization process. This process computes the set of iron loss parameters that allow targeting the considered measurement points.
5	The resulting iron loss input parameters are deduced and displayed in the result table and the corresponding curve; Losses versus B (magnetic flux density) is displayed.
6	The user can adjust one or all the parameters of the iron losses model. To do so user tab must be selected by clicking on its icon. The resulting modification is directly in the outputs area.
7	It is possible to select a frequency to visualize the behavior of the resulting iron loss curve. To do so, use the “Operating” tab. Note: If the chosen frequency is not one of those used for the fitting (from the user inputs), the measurement points (in red) will not be displayed.
8	Validation of iron loss parameters is achieved by clicking on this button. Moreover, it is also possible to cancel the computation of iron loss parameters.

Warning: When characterizing the iron loss parameters by using the method with two measurement points there are two things to be known:

1) Firstly, the internal process uses a genetic algorithm to compute the iron loss parameters.

   When the same frequency is considered for the two targeted points, this can lead to a disparity on the resulting iron loss parameters. It means that, the same set of inputs provide sets of iron loss parameters, which can be different. However, the resulting iron loss model gives the same total amount of iron losses.

   Note: The best way to use the method with two measurement points, is to consider two different frequencies. Thus, there is only one resulting set of iron loss parameters.

   It is highly recommended to take 2 different frequencies as boundaries of the working area.

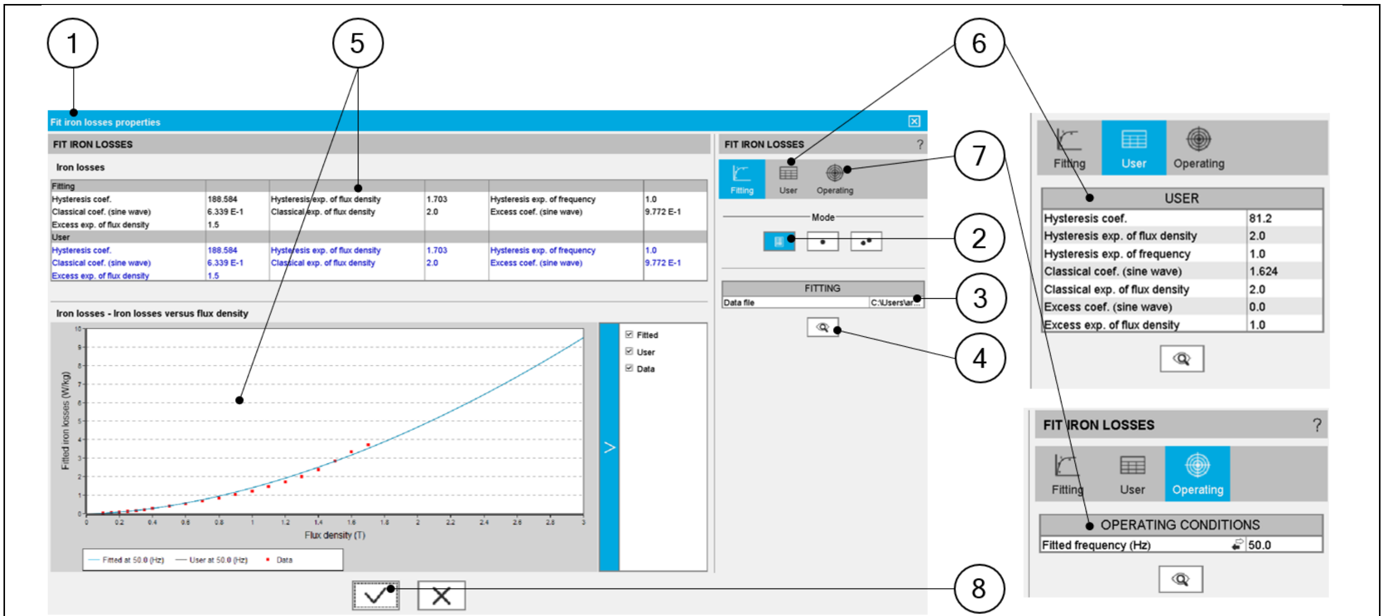
   Moreover, check that the classical losses coefficient is positive before using the resulting iron loss model. If this coefficient is negative, please check the relevance of the original data.

2) Secondly, defining the iron loss parameters, with frequency different from the one which is considered for the computation of a working point in Motor Factory, can lead to wrong results.

The most accurate way to compute iron loss parameters is to use a map of iron losses in f - B plane (f= frequency and B=flux density) where iron losses are defined in function of flux density for different values of frequency.

Note, that to be accurate the frequency and the flux density of the working point to be computed must be respectively in the range of frequencies and flux densities used to identify the iron loss parameters.

4.2.2.4 Case 3: From a map (file input)



Definition of iron loss coefficients – from a map	
1	Dialog box dedicated to fit the iron loss parameters. Located in the “iron losses” category when visualizing or editing the material properties.
2	Choice of the method to find iron loss parameters (form input file in this example).
3	Select the Excel file inside of which several curves of iron losses with flux density functions are available for different values of frequency are defined. An example of file is shown below.
4	When the Excel file is selected, click on the Fit button to run the optimization process. This process computes the set of iron loss parameters targeting the considered measurement points.
5	The resulting iron loss input parameters are deduced and displayed in the result table and the corresponding curve; Losses versus B (magnetic flux density) is displayed.
6	The user can adjust one or all the parameters of the iron losses model. To do so user tab must be selected by clicking on its icon. The resulting modification is directly in the outputs area.
7	It is possible to select a frequency to visualize the behavior of the resulting iron loss curve. To do so, use the “Operating” tab. Note: If the chosen frequency is not one of those used for the fitting (from the user inputs), the measurement points (in red) will not be displayed.
8	Validation of iron loss parameters is achieved by clicking on this button. Moreover, it is also possible to cancel the computation of iron loss parameters.

Example of an Excel file to define the curves of iron losses as a function of flux density for different values of frequency. This corresponds to a map of Iron losses in f - B plane (where f= frequency and B=flux density).

	A	B	C	D	E	F	G	H	I
1									
2		**Iron losses**							
3		**Label**	**Units**	**Values**					
4		Frequency	Hz		**50**	**100**	**200**	**400**	**700**
5		Magnetic induction B	T	**0,10**	0,022	0,049	0,115	0,304	0,699
6		Core loss	W/kg	**0,15**	0,049	0,110	0,260	0,673	1,530
7				**0,20**	0,084	0,188	0,447	1,157	2,624
8				**0,25**	0,125	0,282	0,671	1,739	3,947
9				**0,30**	0,171	0,387	0,926	2,388	5,435
10				**0,35**	0,221	0,503	1,212	3,140	7,165
11				**0,40**	0,276	0,631	1,527	3,977	9,091
12				**0,50**	0,397	0,915	2,235	5,895	13,427
13				**0,60**	0,532	1,237	3,057	8,086	18,697
14				**0,70**	0,683	1,597	3,991	10,683	24,949
15				**0,80**	0,849	2,000	5,017	13,651	32,204
16				**0,90**	1,031	2,442	6,184	17,030	40,521
17				**1,00**	1,234	2,932	7,481	20,810	50,067
18				**1,10**	1,458	3,470	8,894	25,016	60,873
19				**1,20**	1,713	4,086	10,478	29,673	73,213
20				**1,30**	2,014	4,806	12,299	34,904	91,388
21				**1,40**	2,397	5,697	14,557	41,142	118,032
22				**1,50**	2,867	6,852	17,551	49,656	128,825
23				**1,60**	3,368	7,993	20,889	59,960	
24				**1,70**	3,746	8,932	24,808	73,161	
25									

Example of an Excel file to define iron loss parameters from a map

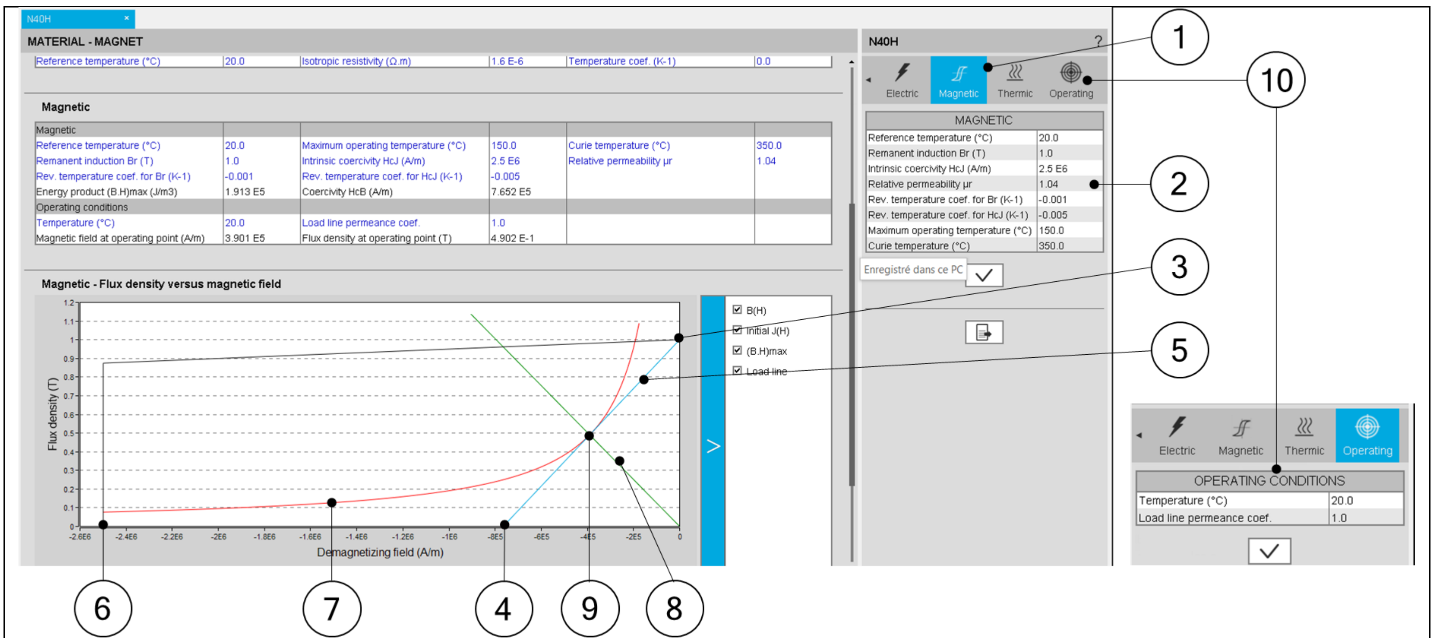
Notes:

- The columns with the larger number of rows must be written first. At least three columns with the same number of rows must be written. In the example above, there are five columns with twenty rows.
- The exponent of B for the excess losses is set to 1.5 in the optimization process.

4.3 Manage magnet parameters

Here is the list of user parameters related to the magnetic behavior of magnets:

Label	Definition
T_{REF}	Reference temperature.
Br at T_{REF}	Remanent flux density at T_{REF}.
α	Reverse temperature coefficient for Br.
μ_r	Relative permeability.
HcJ	Intrinsic coercivity at T_{REF}.
β	Reverse temperature coefficient for HcJ.
$(B.H)_{max}$	Energy product. Disabled input field, value deduced from other inputs.
Hcb	Normal coercivity at T_{REF}. Disabled input field, value deduced from other inputs.
*	Maximum operating temperature. Just for information, not used in computations.
*	Curie temperature. Just for information, not used in computations.



Presentation of the magnet family properties in “Materials”

1	Category dedicated to magnetic properties. Note: Magnetic properties are linked to the data set in the “Operating Conditions” (See item 10 for “Operating”)
2	Input parameters are written in the input area.
3	Remanent flux density (B_r).
4	Normal coercivity (Hcb).
5	B(H) curve for the magnet (in blue).
6	Intrinsic coercivity (HcJ).
7	Isoline $(B.H)_{max}$. (in red).
8	Load line for the defined permeance coefficient (in green)
9	Operating point for the given permeance coefficient and temperature.
10	Temperature and permeance coefficient of the magnetic circuit are defined as “operating conditions” of the magnets. These can be edited in the dedicated tab “Operating”. Any changes will automatically update the outputs. Note: These features have no influence in the magnet physical properties, but these are useful to display its behavior when working at this operating point.

4.4 Thermal impact on quantities computations

4.4.1 Electrical resistivity

Note 1: Only isotropic materials are considered.
Note 2: Resistivity ρ (rho) is a linear function of temperature.

The corresponding mathematical formula for electrical resistivity is:

$$\rho_T = \rho_{REF} \times \left(1 + a \times (T - T_{REF})\right)$$

ρ_T	Resistivity to be defined at a temperature T. Linear function of the temperature for an isotropic or anisotropic material.
T_{REF}	Reference temperature.
T	T is the temperature for which the resistivity must be computed.
ρ_{REF}	Resistivity of the material at T_{REF}.
a	Temperature coefficient at T_{REF}.

4.4.2 Thermal conductivity for all materials except gas and liquid

The thermal conductivity is defined at a reference temperature and is considered as constant for all thermal computations.
The reference temperature is then only a memo, to keep in mind the temperature corresponding to the indicated thermal conductivity.

Symbol	Definition	Unit
T_{ref}	Reference temperature (Tref)	°C
K_{ref}	Isotropic thermal conductivity at Tref W/K/m)	W/K/m

4.4.3 Specific heat variation versus temperature – For all materials except gas and liquid

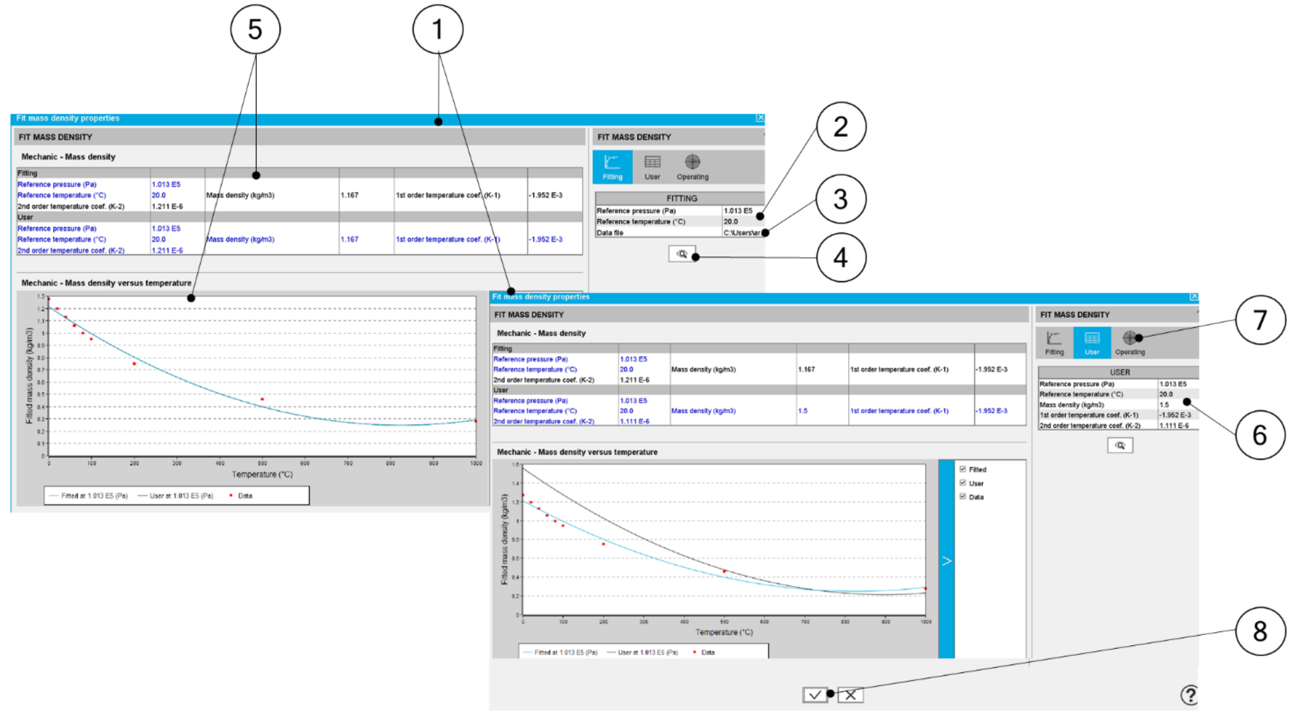
The specific heat is defined at a reference temperature and is considered as constant for all thermal computations.
The reference temperature is then only a memo, to keep in mind the temperature corresponding to the indicated specific heat.

Symbol	Definition	Unit
T_{ref}	Reference temperature (Tref)	°C
C_{ref}	Specific heat at Tref (J/K/Kg)	J/K/Kg

4.4.4 Gas properties

4.4.4.1 Introduction

Here is the process to define and fit the gas thermal characteristics from the importation of series of points representing the considered quantity curve listed in an Excel file. In the following example air mass density is considered, however, the same principle is applied for all other gas properties depending on temperature which are defined below.



Identification of the air mass density curve characteristics (for instance)

1	Dialog box allowing the characterization of the density curve imported from an Excel file
2	Select the reference conditions (temperature and pressure) associated with the measures contained in the Excel file.
3	Path where Excel file containing the measures is stored. See an example of Excel file below.
4	Click on this button to import the Excel data.
5	When importing an Excel file, points representing the density curve are listed, an optimization process automatically computes and displays the corresponding characteristics. Three curves are displayed: • Red points are the imported points (listed in the Excel file) • Blue curve is the resulting curve computed by the optimization process. This corresponds to the computed characteristics and it is displayed just after the computation. • The black curve shows a new curve generated when the parameters are changed by the user (see point 6)
6	Indeed, going to the tab “User” the user can adjust one or all the main parameters of the density curve. • The density at reference temperature • The density first order temperature coefficient • The density second order temperature coefficient Reference temperature and pressure can also be adjusted in this tab.
7	It is possible to select an operating pressure to visualize the behavior of the resulting mass density curve. Operating pressure should be chosen in “Operating” tab. Note: If the chosen pressure is not the same than the ones used for the fitting process, the measurement points (in red) will not be displayed.
8	Lastly the parameters, written in the input fields are validated when the user clicks on this button. It is possible to cancel the creation of the density curve model. In this case, the previous values defined before opening this dialog box are reset.

Example of an Excel file to define the mass density curve parameters.

Mass density curve		
Label	Temperature	Mass density
Units	K	kg/m3
Values	273,15	1,2759
	293,15	1,2
	313,15	1,13
	333,15	1,06
	353,15	1
	373,15	0,95
	473,15	0,75
	773,15	0,46
	1273,15	0,28

Example of an Excel file to define the air mass density curve parameters

4.4.4.2 Mass density

$$\rho_T = \rho_{ref} \times (1 + a \times (T - T_{refD}) + b \times (T - T_{refD})^2)$$

Symbol	Definition	Unit
P_{ref}	Reference pressure	Pa
T_{refD}	Mass density reference temperature T_{refD}	°C
ρ_{ref}	Mass density at T_{refD} and P_{ref}	kg/m3
a	Mass density first order temperature coefficient at T_{refD} and P_{ref}	K-1
b	Mass density second order temperature coefficient at T_{refD} and P_{ref}	K-2

Note 1: The reference pressure mentioned in the previous table is the one considered for defining the gas specific heat.

Note 2: For a given temperature, the gas density (kg/m³) changes with the pressure following the perfect gas law.

The mass density ρ computed at a pressure P is computed as below:

$$\rho_P = \frac{P}{P_{ref}} \times \rho_{P_{ref}}$$

4.4.4.3 Dynamic viscosity

$$\mu_T = \mu_{ref} \times (1 + a \times (T - T_{refV}) + b \times (T - T_{refV})^2)$$

Symbol	Definition	Unit
T_{refV}	Dynamic viscosity reference temperature	°C
μ_{ref}	Dynamic viscosity at T_{refV}	kg/m/s
a	Dynamic viscosity first order temperature coefficient at T_{refV}	K-1
b	Dynamic viscosity second order temperature coefficient at T_{refV}	K-2

Note: The model does not consider any variation of the gas dynamic viscosity with the gas pressure.

4.4.4.4 Thermal conductivity

$$K_T = K_{ref} \times (1 + a \times (T - T_{refC}) + b \times (T - T_{refC})^2)$$

Symbol	Definition	Unit
T_{refC}	Thermal conductivity reference temperature	°C
K_{ref}	Thermal conductivity at T_{refC}	W/K/m
a	Thermal conductivity first order temperature coefficient at T_{refC}	K-1
b	Thermal conductivity second order temperature coefficient at T_{refC}	K-2

Note: The model does not consider any variation of the gas thermal conductivity in function with the gas pressure.

4.4.4.5 Specific heat

$$C_T = C_{ref} \times (1 + a \times (T - T_{refS}) + b \times (T - T_{refS})^2)$$

Symbol	Definition	Unit
T_{refS}	Specific heat reference temperature	°C
C_{ref}	Specific heat at T_{refS} and P_{ref}	J/K/Kg
a	Specific heat first order temperature coefficient at T_{refS} and P_{ref} (K-1)	K-1
b	Specific heat second order temperature coefficient at T_{refS} and P_{ref} (K-2)	K-2

Note 1: All the parameters defined in the previous table are defined for the reference pressure P_{ref} mentioned in the gas mass density section.

Note 2: For a given temperature, the gas specific heat (J/K/kg) changes with the pressure following the perfect gas law.

The specific heat C computed at a pressure P is computed as below:

$$C_P = \frac{P}{P_{ref}} \times C_{P_{ref}}$$

Symbol	Definition	Unit
P_{ref}	Reference pressure	Pa
C_P	Specific heat at the pressure P	J/K/Kg
C_{Pref}	Specific heat at the pressure P_{ref}	J/K/Kg

4.4.4.6 Thermal expansion

The gas property changes with the temperature according to the perfect gas law and is automatically applied in internal processes with the following formula:

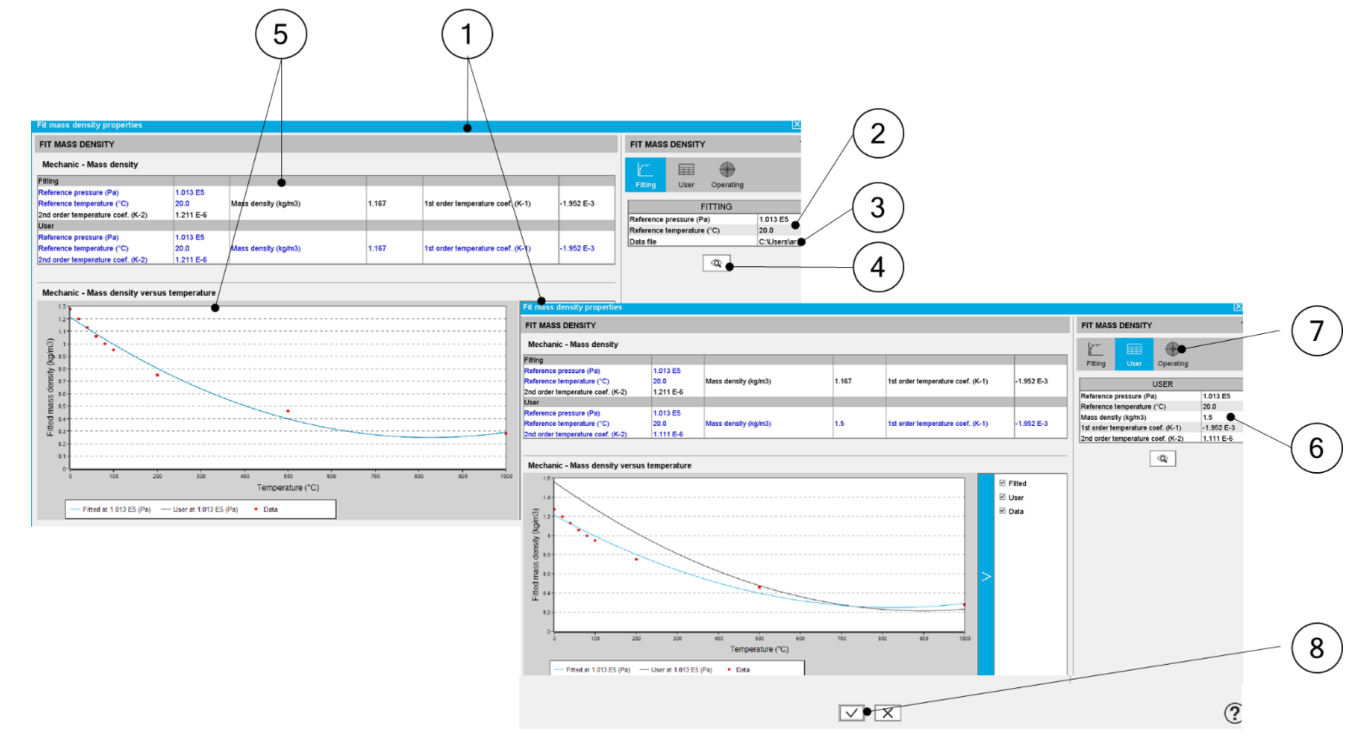
$$\beta_T = \frac{1}{T}$$

Symbol	Definition	Unit
T_{refE}	Temperature at which the thermal expansion must be considered	K
β_T	Thermal expansion coefficient at the temperature T	K-1

4.4.5 Liquid properties

4.4.5.1 Introduction

Here is the process to define the liquid thermal characteristics from the importation of series of points representing the considered quantity curve listed in an Excel file. In the following example water mass density is considered, however, the same principle is applied for all other liquid thermal quantity which are defined below.



Identification of the water mass density curve characteristics (for instance)	
1	Dialog box allowing the characterization of the density curve imported from an Excel file
2	Select the reference temperature associated with the measures contained in the Excel file.
3	Path where Excel file containing the measures is stored. See an example of Excel file below.
4	Click on this button to import the Excel data.
5	When importing an Excel file, points representing the density curve are listed, an optimization process automatically computes and displays the corresponding characteristics. Three curves are displayed: • Red points are the imported points (listed in the Excel file) • Blue curve is the resulting curve computed by the optimization process. This corresponds to the computed characteristics and it is displayed just after the computation. • The black curve shows a new curve generated when the parameters are changed by the user (see point 6)
6	Indeed, going to the tab "User" the user can adjust one or all the main parameters of the density curve. • The density at reference temperature • The density first order temperature coefficient • The density second order temperature coefficient Reference temperature can also be adjusted in this tab.
7	Lastly parameter values, written in the input fields are validated when the user clicks on this button. It is possible to cancel the creation of the density curve model. In this case, the previous values defined before opening this dialog box are reset.

Example of an Excel file to define the water mass density curve parameters.

Mass density curve		
Label	Temperature	Mass density
Units	K	kg/m3
Values	273,15	999,9
	283,15	999,6
	293,15	998,2
	303,15	995,6
	313,15	992,3
	323,15	988
	333,15	983,2
	343,15	977,7
	353,15	971,8
	363,15	965,3
	373,15	958,3

Example of an Excel file to define the water mass density curve parameters

4.4.5.2 Mass density

$$\rho_T = \rho_{ref} \times (1 + a \times (T - T_{refD}) + b \times (T - T_{refD})^2)$$

Symbol	Definition	Unit
T_{refD}	Mass density reference temperature T_{refD}	°C
ρ_T	Mass density at T_{refD}	kg/m3
a	Mass density first order temperature coefficient at T_{refD}	K-1
b	Mass density second order temperature coefficient at T_{refD}	K-2

Note 1: Liquids are considered as incompressible in FluxMotor®. Their properties are constant versus the pressure.

4.4.5.3 Dynamic viscosity

$$\mu_T = \mu_{ref} \times (1 + a \times (T - T_{refV}) + b \times (T - T_{refV})^2)$$

Symbol	Definition	Unit
T_{refV}	Dynamic viscosity reference temperature	°C
μ_{ref}	Dynamic viscosity at T_{refV}	kg/m/s
a	Dynamic viscosity first order temperature coefficient at T_{refV}	K-1
b	Dynamic viscosity second order temperature coefficient at T_{refV}	K-2

4.4.5.4 Thermal conductivity

$$K_T = K_{ref} \times (1 + a \times (T - T_{refC}) + b \times (T - T_{refC})^2)$$

Symbol	Definition	Unit
T_{refC}	Thermal conductivity reference temperature	°C
K_{ref}	Thermal conductivity at T_{refC}	W/K/m
a	Thermal conductivity first order temperature coefficient at T_{refC}	K-1
b	Thermal conductivity second order temperature coefficient at T_{refC}	K-2

Note 1: Liquids are considered as incompressible in FluxMotor®. Their properties are constant versus the pressure.

4.4.5.5 Specific heat

$$C_T = C_{ref} \times (1 + a \times (T - T_{refS}) + b \times (T - T_{refS})^2)$$

Symbol	Definition	Unit
T_{refS}	Specific heat reference temperature - T_{refS} (°C)	°C
C_{ref}	Specific heat at T_{refS}	J/K/Kg
a	Specific heat first order temperature coefficient at T_{refS}	K-1
b	Specific heat second order temperature coefficient at T_{refS}	K-2

Note 1: Liquids are considered as incompressible in FluxMotor®. Their properties are constant versus the pressure.

4.4.5.6 Thermal expansion

$$\beta_T = \beta_{ref} \times (1 + a \times (T - T_{refE}) + b \times (T - T_{refE})^2)$$

Symbol	Definition	Unit
T_{refE}	Thermal expansion reference temperature	°C
β_{ref}	Thermal expansion coefficient at T_{refE}	K-1
a	Thermal expansion first order temperature coefficient at T_{refE}	K-1
b	Thermal expansion second order temperature coefficient at T_{refE}	K-2

4.4.6 Magnet properties

4.4.6.1 Remanent flux density of magnets

Note 1: Only isotropic magnet is considered.
Note 2: Remanent flux density (Br) is a linear function of the temperature.

The corresponding mathematical formula is:

$$\mathrm{Br}_T = \mathrm{Br}_{ref} \times \left(1 + \mathrm{a} \times (\mathrm{T} - \mathrm{T_{ref}})\right)$$

Br_{T}	Remanent flux density to be defined at a temperature T. Linear function of the temperature for an isotropic or anisotropic material.
T_{ref}	Reference temperature.
T	T is the temperature for which the remanent flux density must be computed.
Br_{ref}	Remanent flux density of the magnet at T_{REF}.
a	Reverse temperature coefficient for Br at T_{REF}.

4.4.6.2 Intrinsic coercivity

Note 1: Only isotropic magnet is considered.
Note 2: Intrinsic Coercivity (HcJ) is a linear function of the temperature.

The corresponding mathematical formula is:

$$\mathrm{HcJ}_T = \mathrm{HcJ}_{ref} \times \left(1 + \mathrm{a} \times (\mathrm{T} - \mathrm{T_{ref}})\right)$$

HcJ_{T}	Intrinsic Coercivity to be defined at a temperature T. Linear function of the temperature for an isotropic or anisotropic material.
T_{REF}	Reference temperature.
T	T is the magnet temperature for which the Intrinsic Coercivity must be computed.
HcJ_{ref}	Intrinsic Coercivity of the magnet at T_{REF}.
a	Reverse temperature coefficient for HcJ at T_{REF}.