Altair® FluxMotor® 2025

Direct Current Permanent Magnet Machine - Inner rotor

Motor Factory – Design

General user information

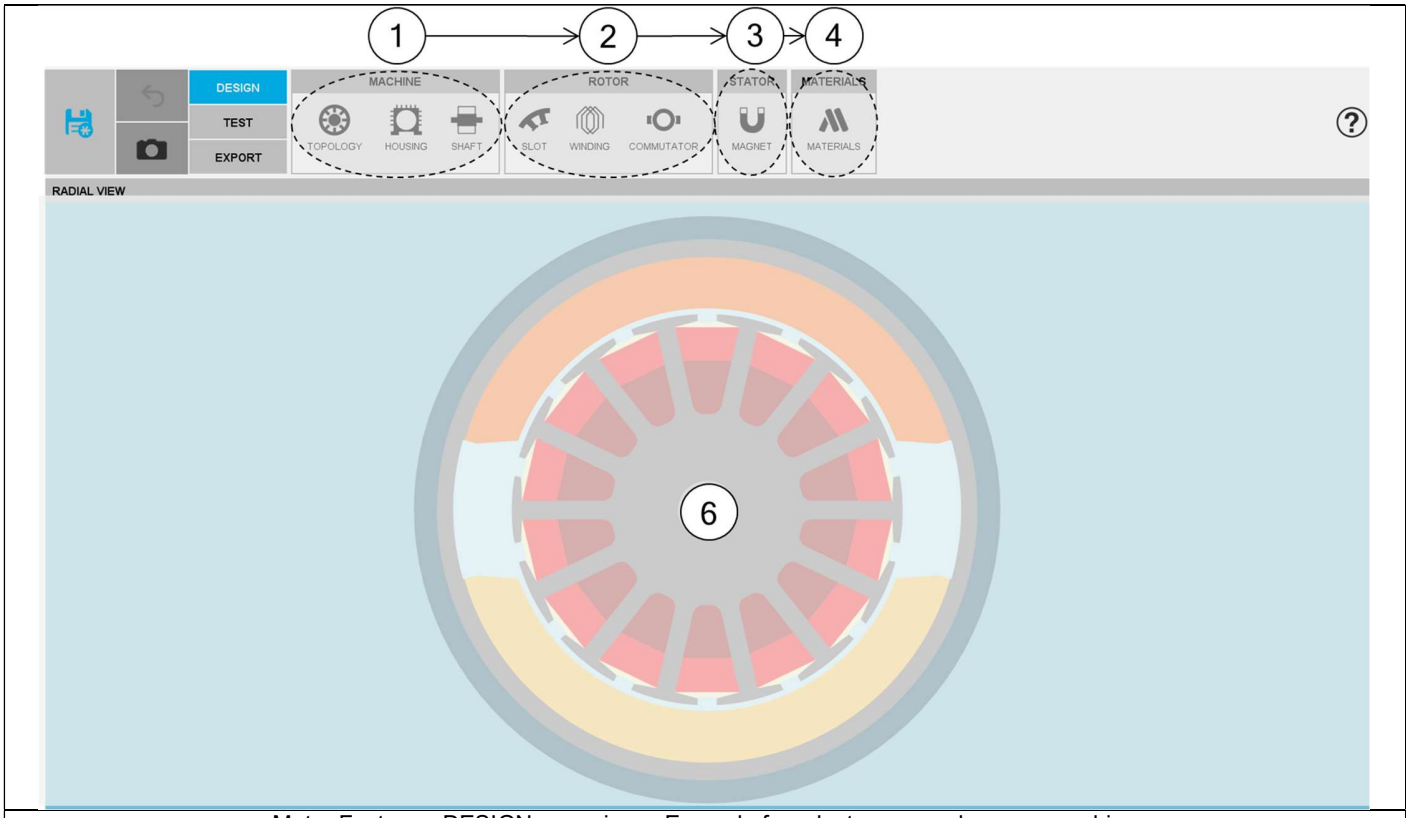
Altairhyperworks.com

Contents

1 DIRECT CURRENT PERMANENT MAGNET MACHINE

1.1 Home page view

The Motor Factory – DESIGN area is the first environment of Motor Factory.
It is composed of four main zones. This is the guided line to design your machine.



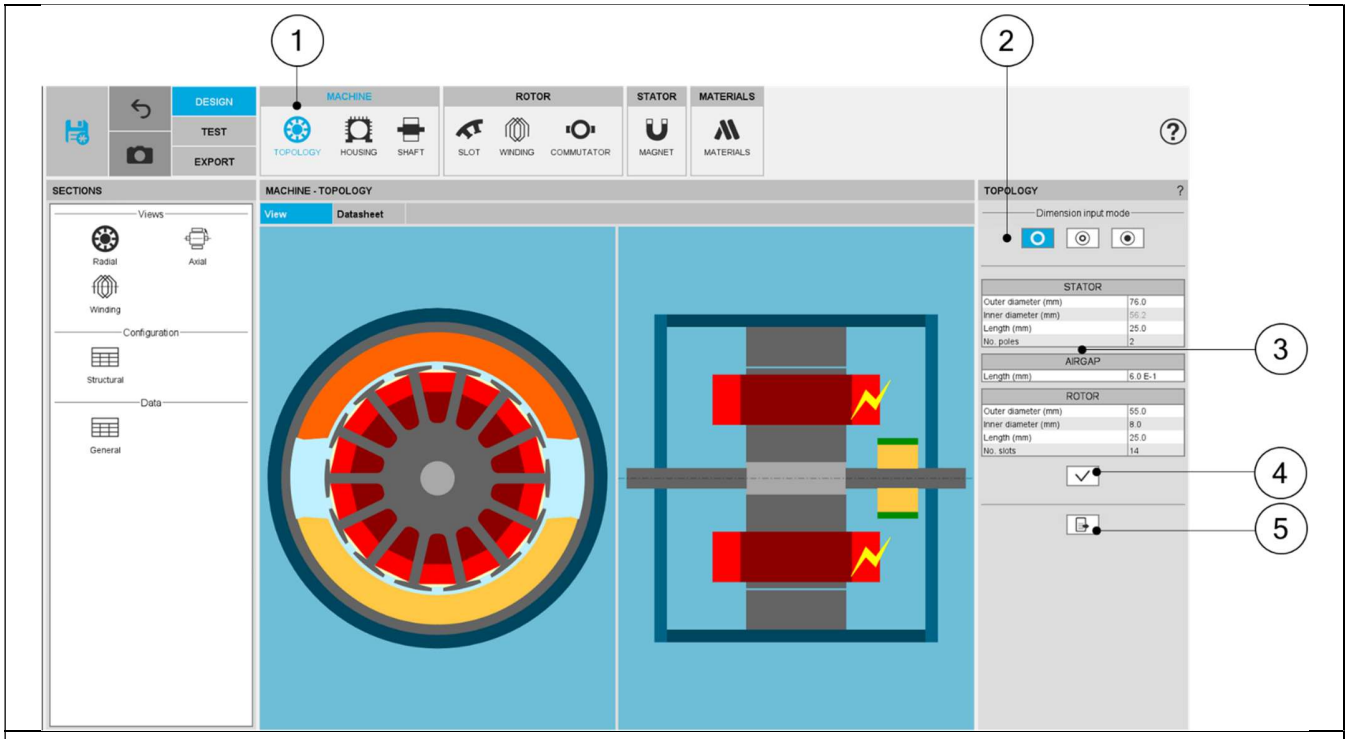
Motor Factory – DESIGN area view – Example for reluctance synchronous machine

Zone 1 **MACHINE**	Definition of general data of the machine depending on the considered type of machine • Topology with overall dimensions, No. slots, No. poles, • Housing topology and dimensions • Shaft type and dimensions
Zone 2 **ROTOR**	Access to the main functions to design the ROTOR mainly defined by: • Slot • Winding • Commutator
Zone 3 **STATOR**	Access to the main functions to design the STATOR mainly defined by: • Magnet
Zone 4 **MATERIALS**	Area to select all the materials required to build the machine, rotor, stator, etc.
Zone 5 **VIEW**	Visualization of the motor radial view. The winding (automatically defined) is shown. Note: Graphic functions like export picture and zoom are available on this view by right clicking on mouse (right part of the panel). See system functions, graphic management to get more information.

1.2 Topology

1.2.1 Overview

The first step of the design consists of defining structural data of the machine.
However, at any time, it is possible to reach and modify the structural data from the Motor Factory design environment.
Here is the process to modify the structural data from the general data panel.



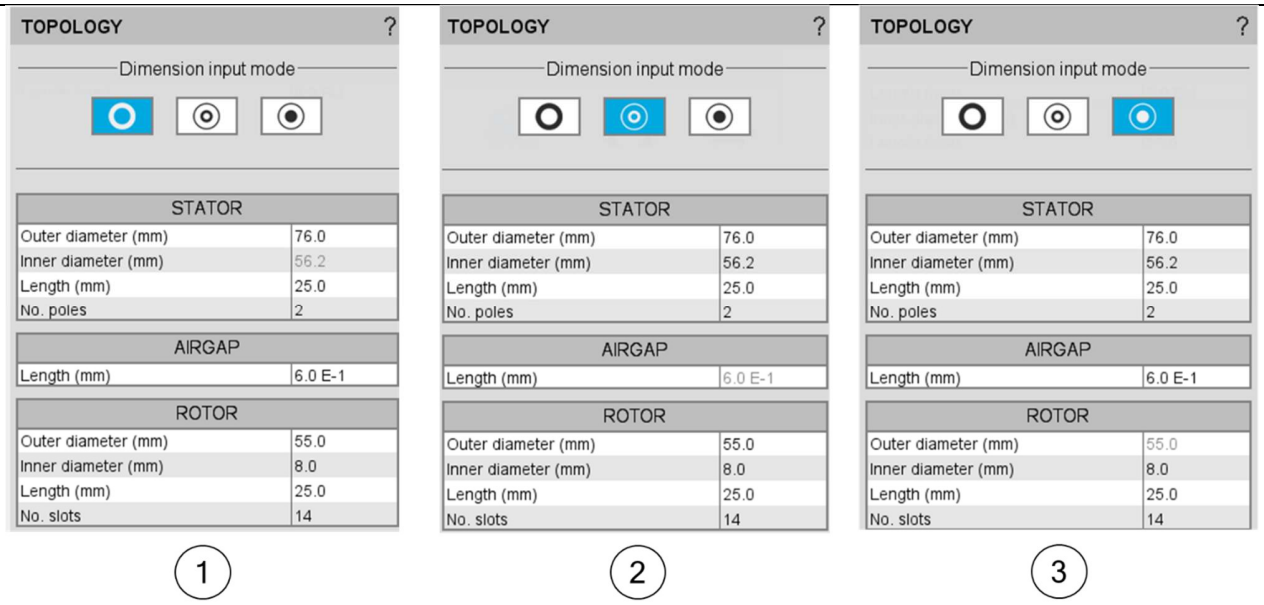
Process to modify the structural data	
1	Open the TOPOLOGY panel (Click on the icon TOPOLOGY)
2	Choose a way to define the diameters of the machine and the airgap See additional information below.
3	Modify the values of structural data – When relevant, the corresponding arrow is displayed on the view
4	Button to apply inputs
5	Icon to export data into *.txt or *.xlsx file - Please see above illustration

For more details concerning general functions of Motor Factory Design environment, please refer to the document MotorFactory_Introduction".

1.2.2 Inputs

1.2.2.1 Method to define the airgap

In the topology sub area, three ways are possible to define the structural data of the machine based upon the diameters and the airgap. They are illustrated below.



Method to define the diameters of machine and the airgap
Example for the Direct Current Permanent Magnet machine

1	User defines the inner diameter of the stator and the airgap. The outer diameter of the rotor is automatically deduced (automatically computed value is displayed in grey color).
2	User defines the inner diameter of the stator and the outer diameter of the rotor. The airgap is automatically deduced (automatically computed value is displayed in grey color).
3	User defines the outer diameter of the rotor and the airgap. The inner diameter of the stator is automatically deduced (automatically computed value is displayed in grey color).

1.2.2.2 Structural data

Here are the user input parameters to define the structural data of the machine:

- Stator outer diameter
- Stator inner diameter
- Stator length
- Number of poles
- Airgap length
- Rotor outer diameter
- Rotor inner diameter
- Rotor length
- Number of slots

The modification of the structural data can lead to the modification of the user input parameters in defining dimensions of parts like slots or magnets. When modifications occur, a warning is displayed.
The application ranges for structural data are defined below.

1.2.3 Advice for use

The choice of diameters is possible over the range [1, 20000] mm.
The number of slots is possible over the range [3, 2400].
The number of poles is possible over the range [2, 400].

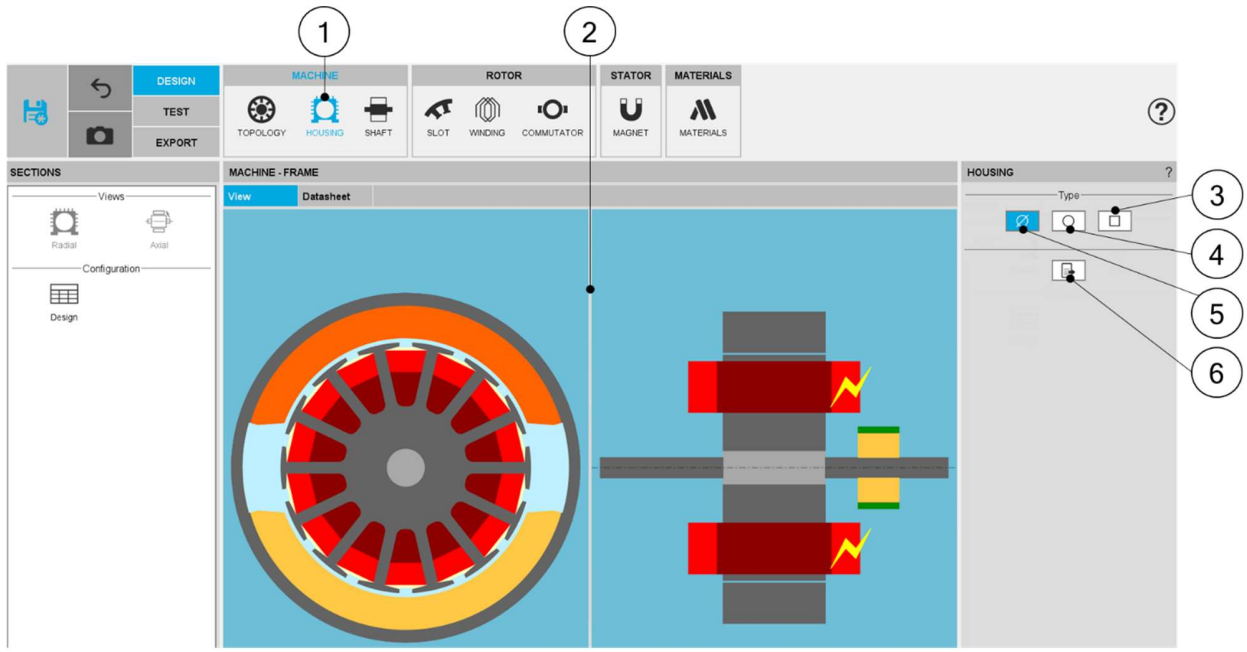
Note: Our processes for building and computations have been qualified over the following data ranges:

Range for diameters [1, 1000] mm.
Range for number of slots [3, 90].
Range for number of poles [2, 80].

Working beyond these limits is possible but accurate results are the responsibility of the user.

1.3 Housing

1.3.1 Overview



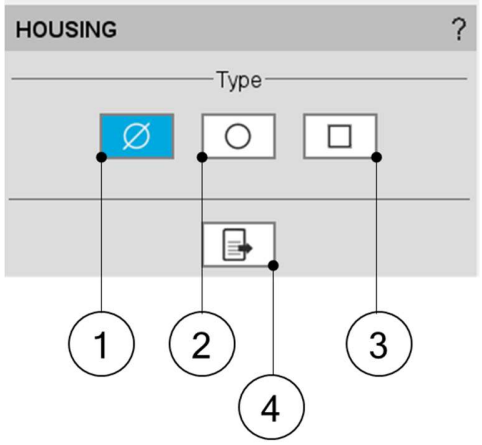
HOUSING design area	
1	Selection of the MACHINE subset: HOUSING panel (Click on the icon HOUSING)
2	Radial and axial view of the motor.
3-4-5	Three choices are available to define the lamination topology: None, Circular and Square
3	Choice of a square shape lamination. See additional information below
4	Choice of a circular shape lamination. See additional information below
5	Choice of “None” meaning that the outer shape of lamination is circular. Outer dimensions of lamination are indicated in general data (structural data part).
6	Icon to export lamination data into *.txt or *.xlsx files.

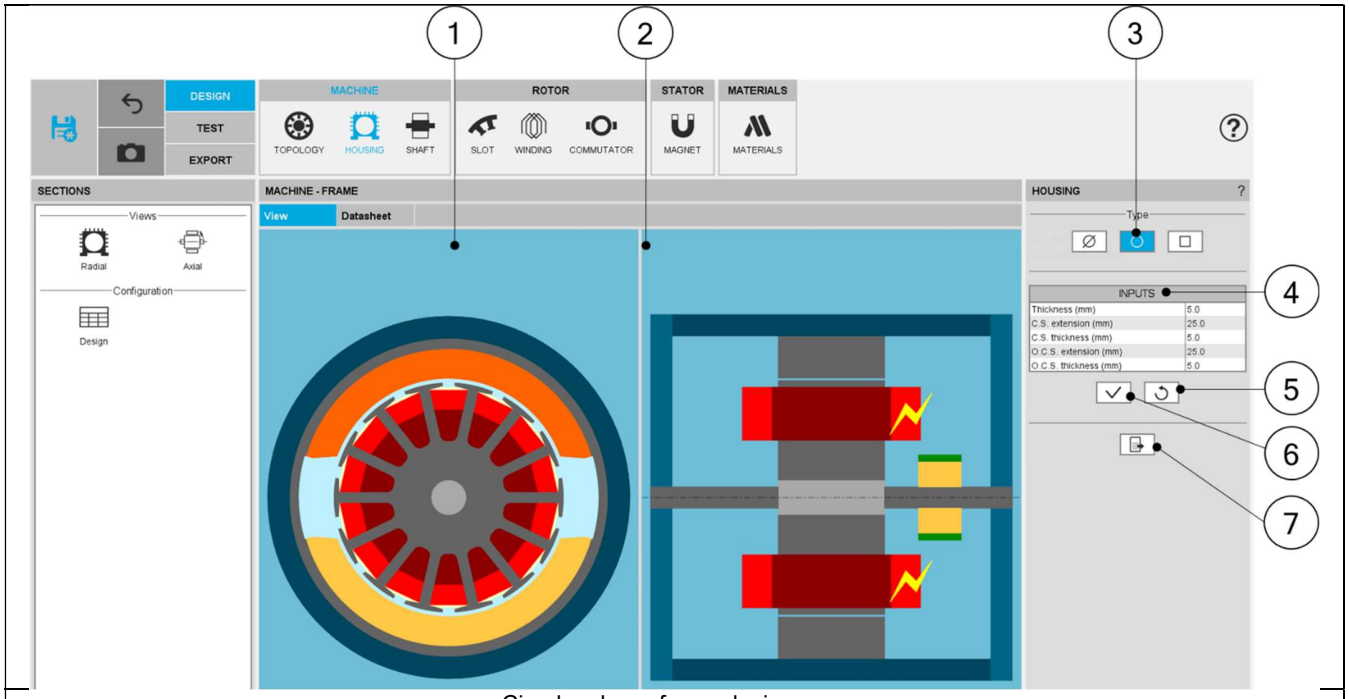
1.3.2 Housing - Frame

1.3.2.1 Type of frame

The tools available in the housing tab allow defining the frame topology.
Three choices are available to define this topology: None, Circular or Square.

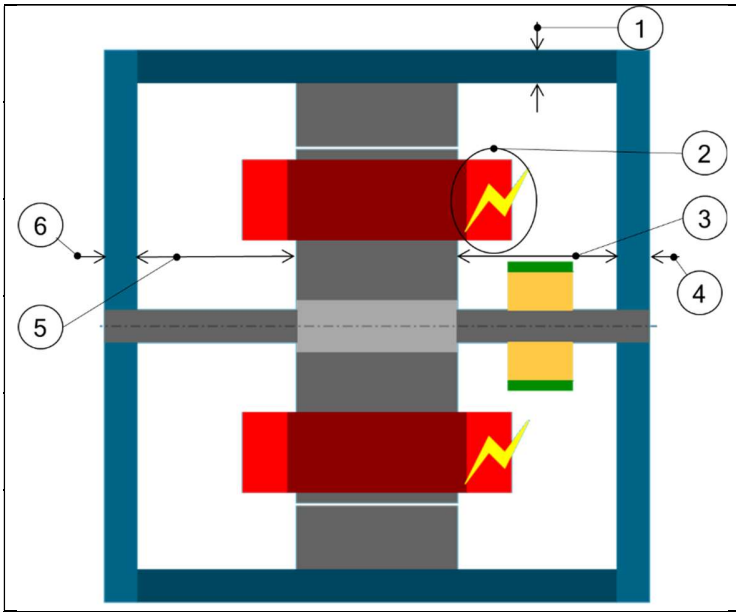
By default, housing type is set to “None”. There is no frame.

	
1	Default setting : Housing type is « None » The machine has no frame.
2	Button to select a Circular shape frame.
3	Button to select a Square shape frame.
4	Icon to export frame data into *.txt or *.xlsx files.
Frame type available	



Circular shape frame design area

1	Radial view of the motor, including the housing topology and dimensions.
2	Axial view of the motor, including the housing topology and dimensions.
3	Selected button to set a circular shape frame.
4	User input parameters to define the frame dimensions. For more information see below.
5	Button to restore default input values.
6	Button to apply inputs. Pressing the enter key twice applies inputs too.
7	Icon to export frame data into *.txt or *.xlsx files.

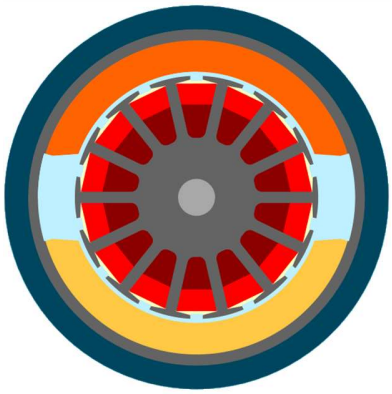


1	Thickness of the frame. Allowed range of values]0, 50] mm.
2	Connection side (C.S.) is identified by yellow lightning.
3	Connection side extension. Allowed range of values [0, 20000] mm.
4	Connection side – End-plate thickness. Allowed range of values [0, 50] mm.
5	Opposite connection side extension. Allowed range of values [0, 20000] mm.
6	Opposite connection side – End-plate thickness. Allowed range of values [0, 50] mm.

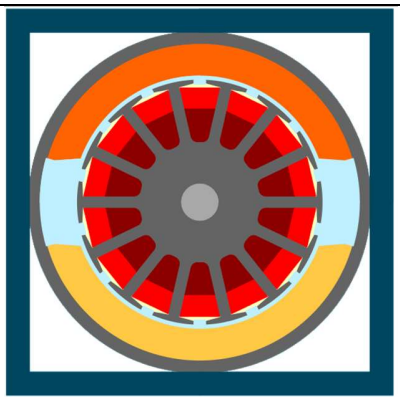
User input parameters to define frame dimensions in the axial view

1.3.2.2 Combination between lamination outer shape and frame types

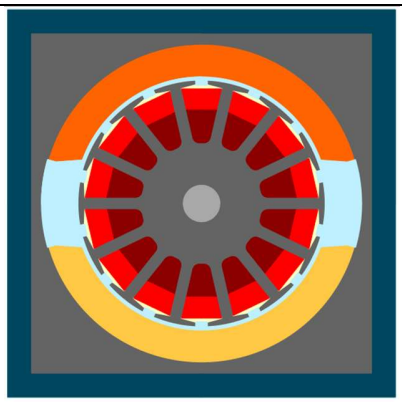
		Frame type		
		None	Circular	Square
Lamination outer shape	None	v	v	v
	Circular	v	v	v
	Square	v	Not possible	v



Circular shape lamination & Circular shape frame



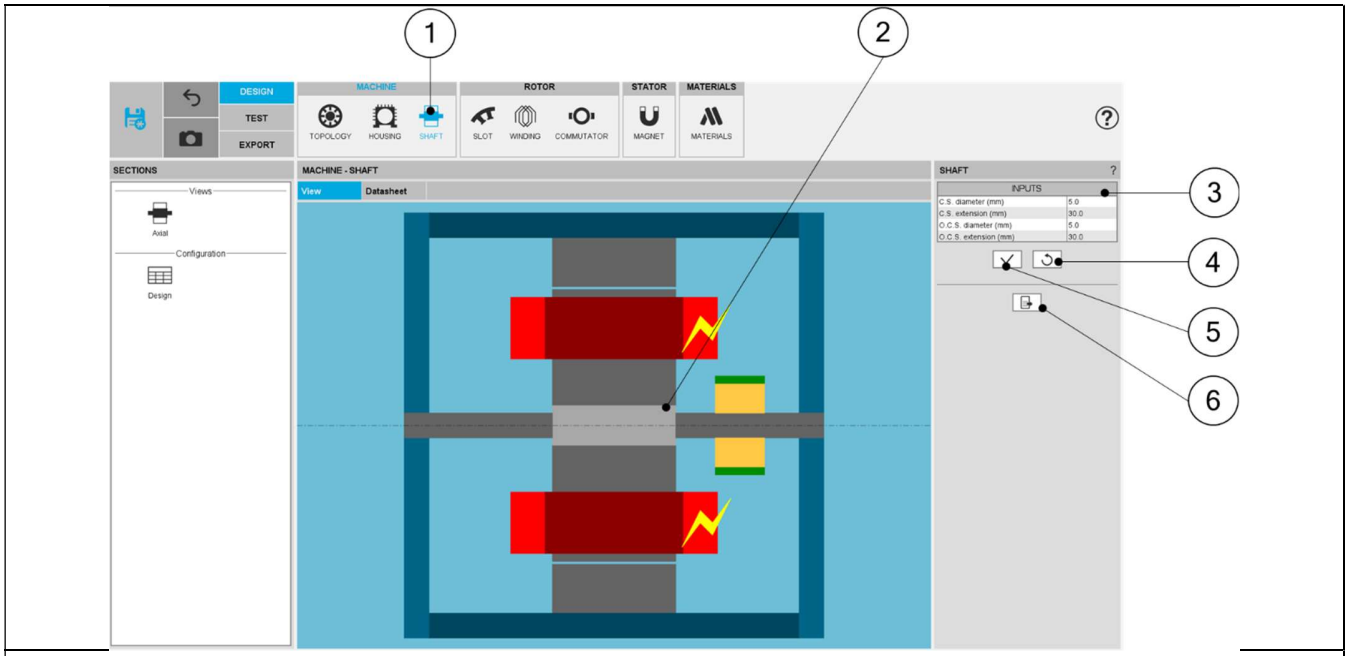
Circular shape lamination & Square shape frame



Square shape lamination & Square shape frame

1.4 Shaft

1.4.1 Overview



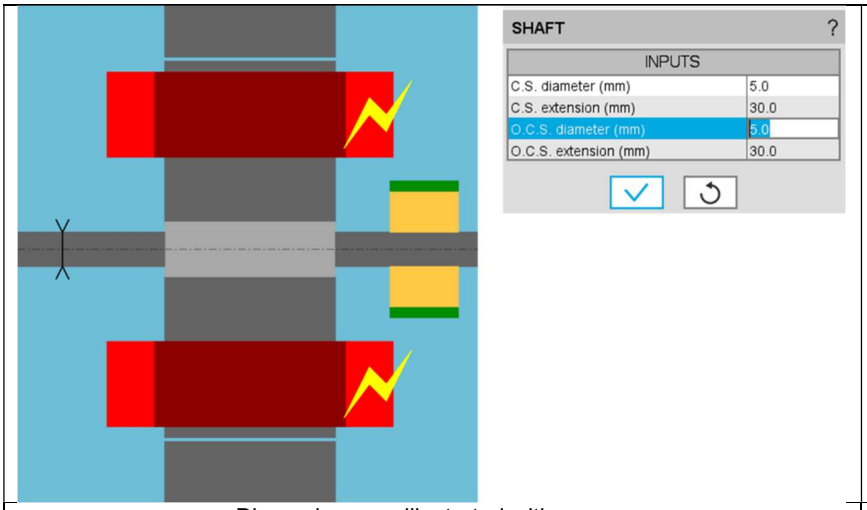
SHAFT design area

1	Selection of the MACHINE subset: SHAFT panel (Click on the icon SHAFT)
2	Visualization of the motor axial view to visualize the shaft topology and dimensions.
3	Shaft input data to be defined
4	Button to restore default input values
5	Button to Apply inputs. Pressing the enter key twice applies inputs too.
6	Icon to export shaft data into *.txt or *.xlsx files.

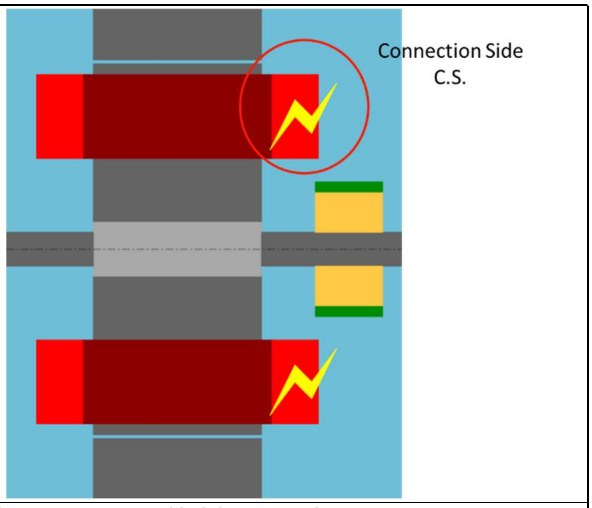
Note: Notice that for a DC machine a shaft must always be defined, since it is necessary to support the commutator.

1.4.2 Shaft type

For DC PM machine a solid shaft is imperatively selected, i.e. shaft is always represented and considered in the rotor design. It is built with a solid material or laminations



Dimensions are illustrated with arrows



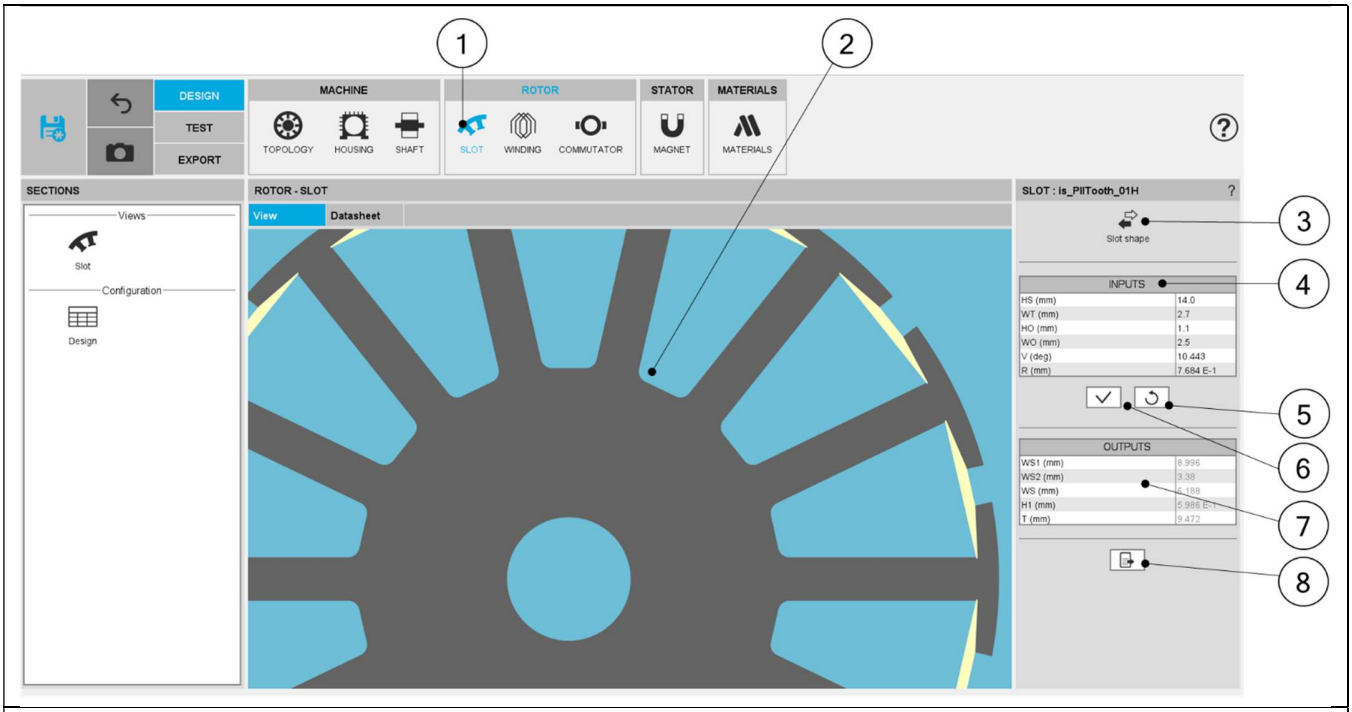
Connection side (C.S.) is identified by yellow lightning.

1.4.3 Shaft - Inputs

Label	Symbol	Tooltip, note, formula
C.S. diameter	D1	Connection side end-shaft diameter.
C.S. extension	L1	Connection side end-shaft extension.
O.C.S. diameter	D2	Opposite connection side end-shaft diameter.
O.C.S. extension	L2	Opposite connection side end-shaft extension.

1.5 Slot

1.5.1 Overview

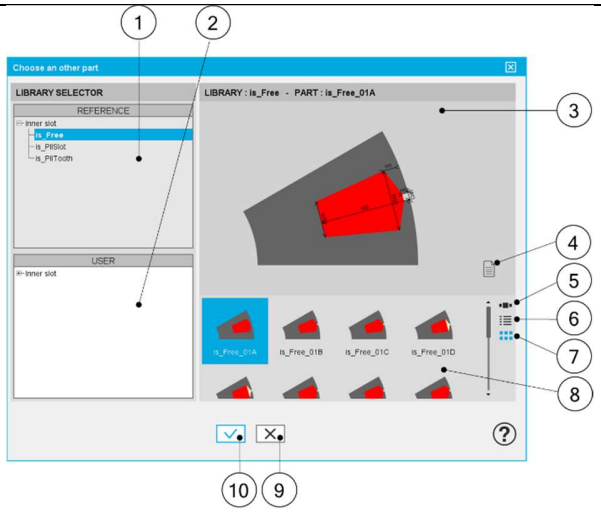


SLOT design area	
1	Selection of the STATOR subset: SLOT panel (Click on the icon SLOT)
2	Visualization of the motor radial view to see the slot topology and dimensions.
3	"Slot shape" button allows accessing the slot libraries to change the slot topology. See additional information below.
4	User input parameter fields.
5	Button to restore default input values.
6	Button to Apply inputs. Pressing the enter key twice applies inputs too.
7	Output parameters (read only data) to complete the description of the topology.
8	Icon to export slot data into *.txt or *.xlsx files.

1.5.2 Slot - Design

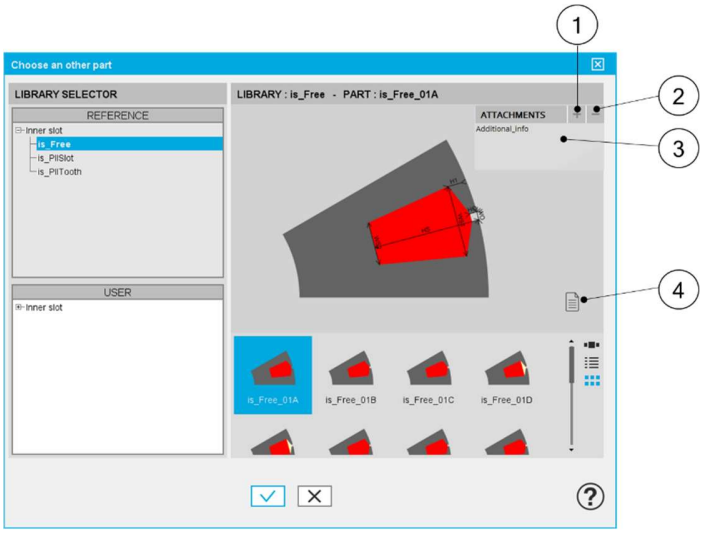
1.5.2.1 Slot shape - Choose a slot topology

Clicking on the "Slot shape" button opens a dialog box, allowing access to the slot libraries.
It allows visualizing, comparing, choosing, and importing another slot topology to modify in the current stator design.



How to choose another slot topology?	
1	Visualization of reference libraries i.e., the libraries of slot topologies provided with FluxMotor®. Select them to view their content and choose the slot among them. See “Part Library” application for more information.
2	Visualization of user libraries. The default user library is “User_InnerSlot” See “Part Library” application for more information.
3	Area where the selected slot is displayed (static picture) – Topology + dimension labels.
4	Button to visualize the list of documents attached to the part. See additional information below.
5	Button to display thumbnails as a slide show.
6	Button to display thumbnails as a list.
7	Button to display thumbnails as a matrix view of pictures.
8	Area to visualize all the topologies of slots from the selected library (ref. 1).
9	Button to close the dialog box and come back to Motor Factory – DESIGN – Slot area.
10	Button to choose and import the selected slot to modify the current stator design.

1.5.2.2 Attached documents – Additional information



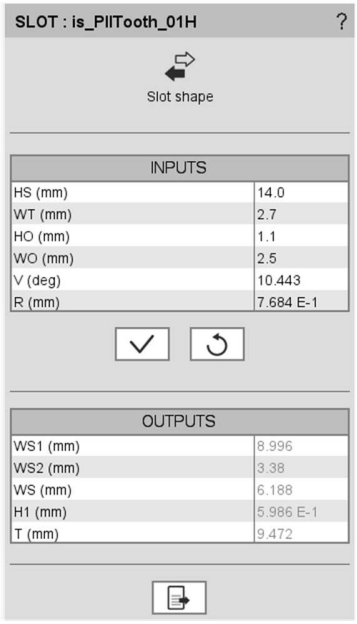
1	Attached document list after having clicked on button to display it (4).
2	“+” or “-“ non-active buttons from “Motor Factory”. See “Part Library” application for more information.
3	List of attached documents (if present). A double click on the selected document opens it. Documents can be added only from Part Library application. See “Part Library” application for more information.
4	Button to show or hide the attached document list.

Visualization of attached documents

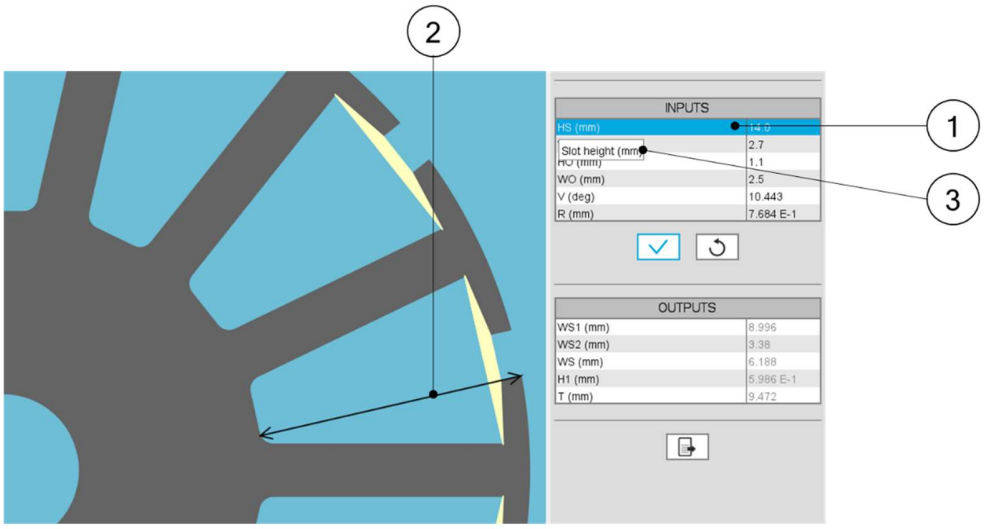
1.5.2.3 Inputs / Outputs

Specific inputs and outputs are considered for each slot topology.
The relevance of input parameters values can be evaluated by using “Part Factory” application.
See “Part Factory” application for more information.

Outputs are read only data. They complete the description of the topology.



Inputs / Outputs of parts

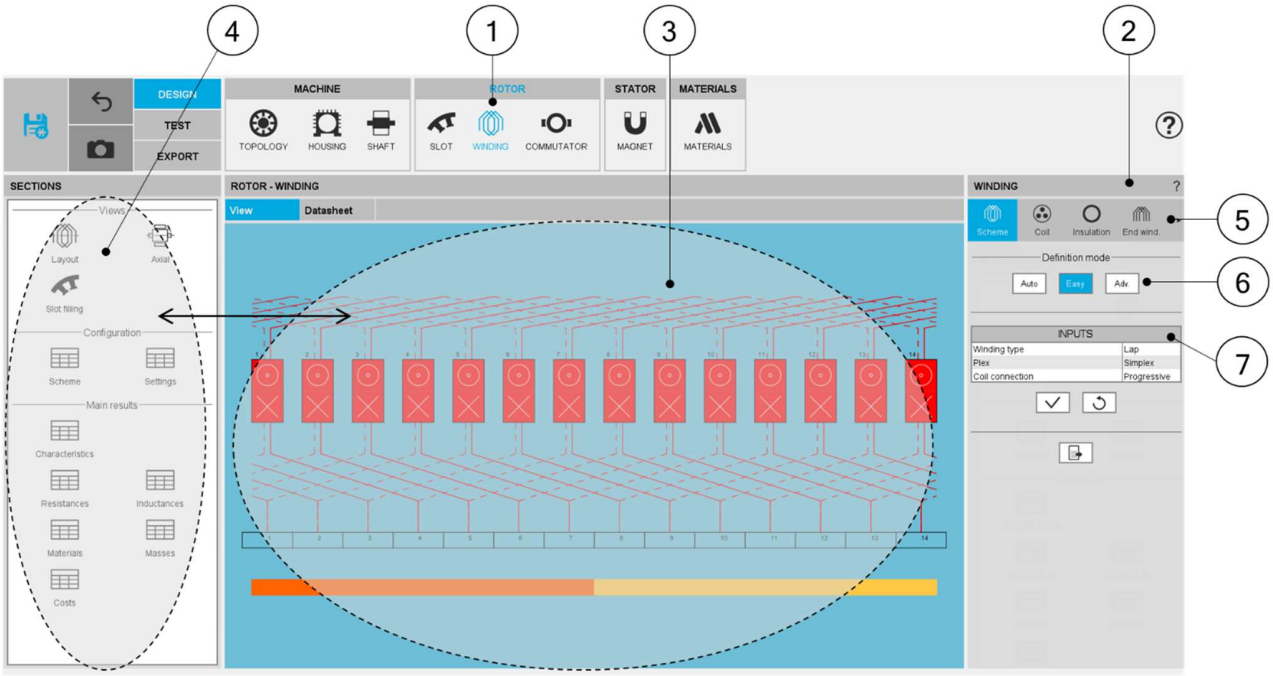


Inputs / Outputs stator slot

1	Select a parameter highlights it.
2	Select a parameter label displays the corresponding arrow on the picture.
3	Select a parameter displays the corresponding tooltip which completes information about the parameter.

1.6 Winding

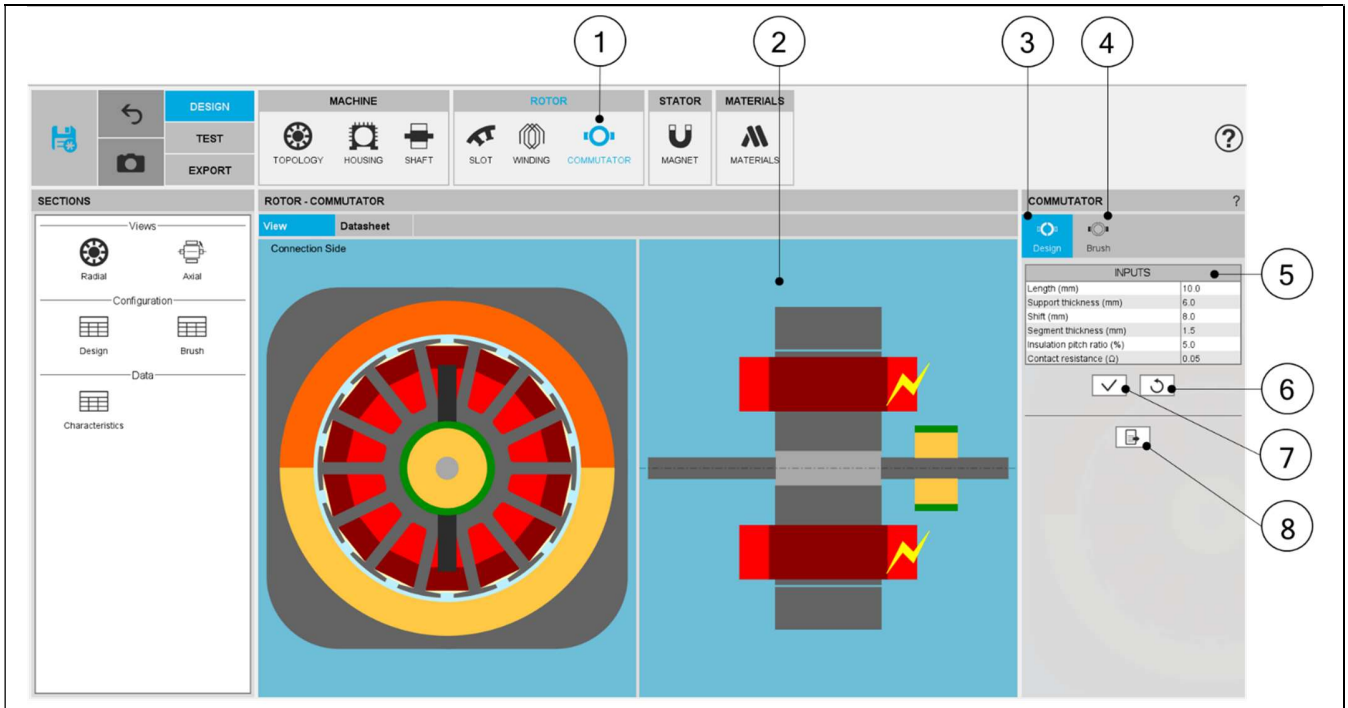
Please refer to the user help guide “Windings” to get more general user information.



WINDING design area – Overview	
1	Selection of the ROTOR subset: WINDING panel (Click on the icon WINDING)
2	All the required user inputs to define the winding are available in the “WINDING” panel (right part).
3	Once a winding is defined, the corresponding results are automatically displayed in the form of a winding report. Visualization of the winding characteristics (inputs, settings, materials, etc) are possible. Scrollbars allow browsing the whole document rapidly and giving an overview of all the results. Using scrollbars, complete data can be accessed and visualized.
4	Shortcuts for displaying the corresponding section of the winding report.
5	A section scrolling bar allows choosing the section in which user inputs are defined. Scrolling selection bar where Winding architecture, Coil, Insulation, End-winding and X-Factor sections can be selected
6	Three modes of winding allow to **define and build the winding architecture**.
Auto	**Automatic** mode, used as default.
Easy	**Easy** mode, to choose solution among those FluxMotor® proposes.
Adv.	**Advanced** mode, to allow the user to define any specific input parameters.
7	User input parameter fields to enter the values according to the considered mode.

1.7 Commutator

1.7.1 Overview



COMMUTATOR design area –Overview

1	Selection of the ROTOR subset: COMMUTATOR panel (Click on the icon COMMUTATOR)
2	Visualization of the motor axial and radial views to visualize the commutator and the brushes
3	Commutator design tab to stablish global parameters, both geometrical and electrical
4	Brush design tab to introduce brush related parameters
5	Commutator-Design input data to be defined
6	Button to restore default input values
7	Button to apply inputs. Pressing the enter key twice applies inputs too.
8	Icon to export shaft data into *.txt or *.xlsx files.

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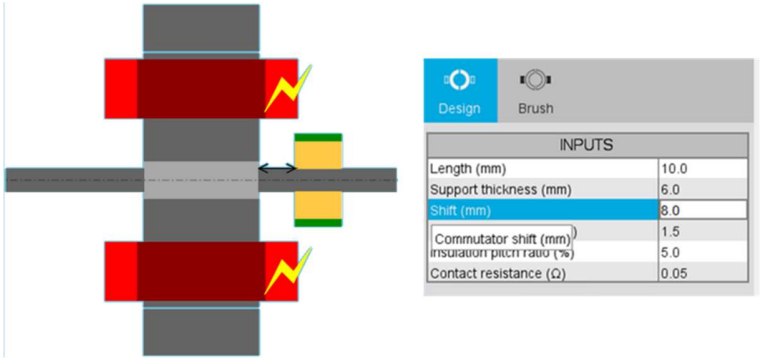
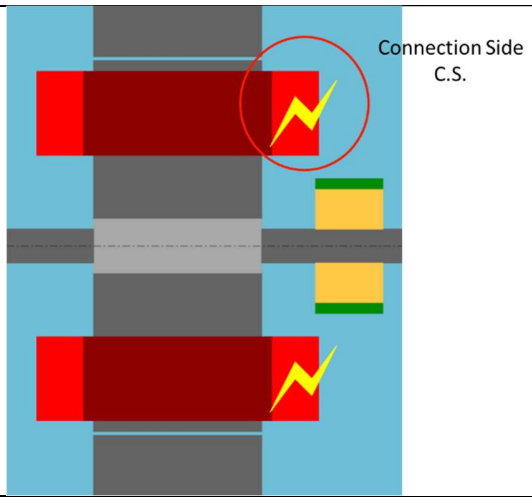
1.7.2 Commutator – Design input parameters

Note: By definition, the commutator is always placed in the connection side (C.S.) which is identified by a yellow lighting.

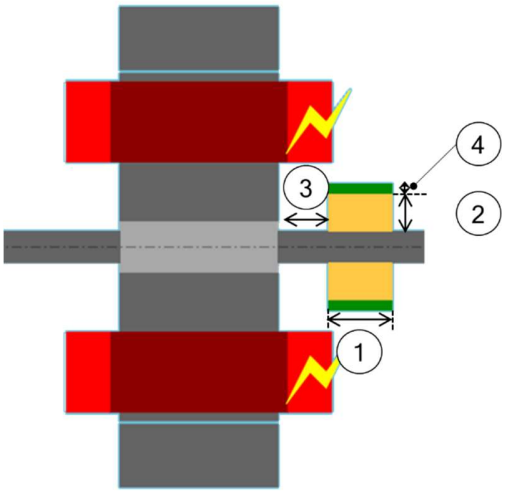
Label	Tooltip, note
Length	Commutator axial length.
Support thickness	Thickness of the not conducting material that is supporting the commutator segments. Since it has cylindrical form it corresponds to its radius.
Shift	Commutator shift
Segmentation thickness	Thickness of the conductive commutator segments.
Insulation pitch ratio	Angular ratio of the insulation between commutator segments
Contact resistance	Contact resistance between the brushes and the commutator segments



Dimensions are illustrated with arrows

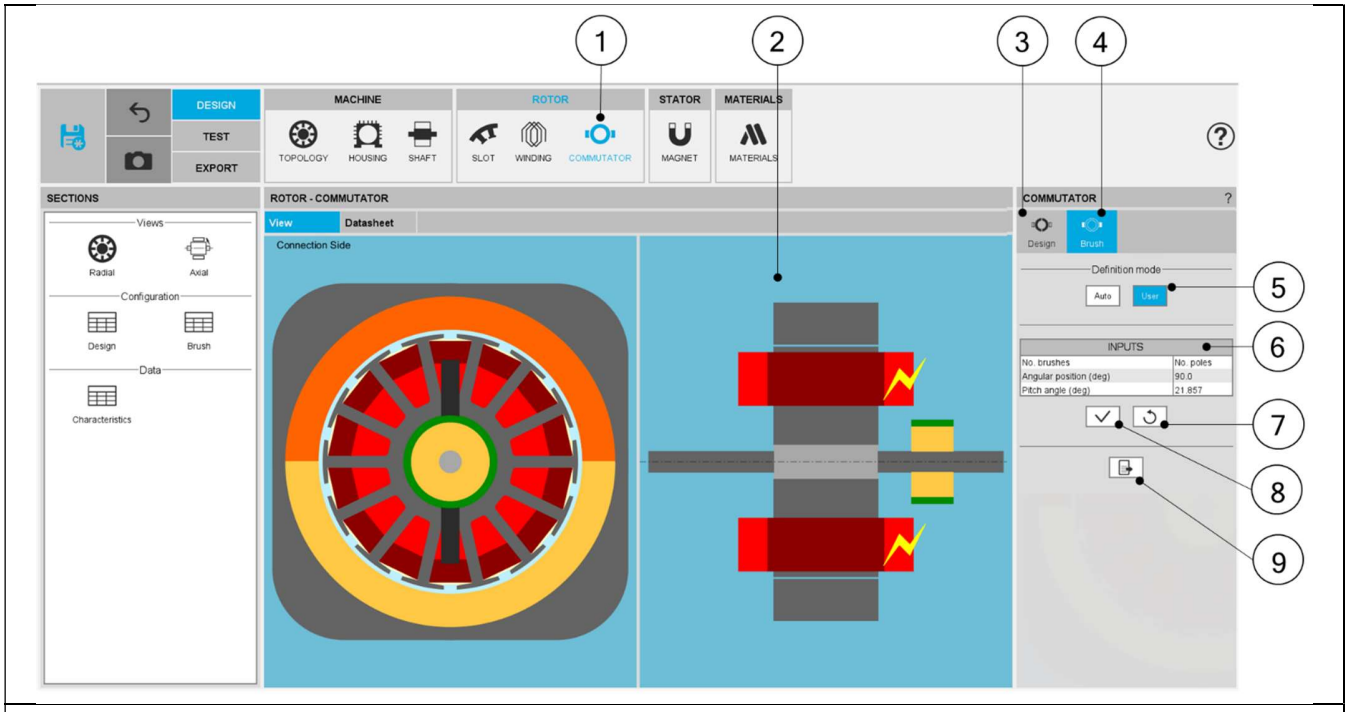


The commutator is always placed in the connection side (C.S.) which is identified by a yellow lighting



Commutator geometrical parameters	
1	Length
2	Support thickness
3	Shift
4	Segmentation thickness

1.7.3 Commutator – Brush - Overview



COMMUTATOR – Brush - Overview	
1	Selection of the ROTOR subset: COMMUTATOR panel (Click on the icon COMMUTATOR)
2	Visualization of the motor radial and axial views to visualize the commutator topology including brushes
3	Commutator design tab to stablish global parameters, both geometrical and electrical
4	Brush design tab to introduce brush related parameters
5	Choice of the commutator-brush definition mode. Two options are available: • Auto: Brushes dimensions and angular position are automatically calculated by FluxMotor to get the best fit with the defined winding (see below) • User: Brushes dimensions and angular position are defined by the user
6	Commutator-brush input data to be defined (only available in user mode)
7	Button to restore default input values
8	Button to apply inputs. Pressing the enter key twice applies inputs too.
9	Icon to export shaft data into *.txt or *.xlsx files.

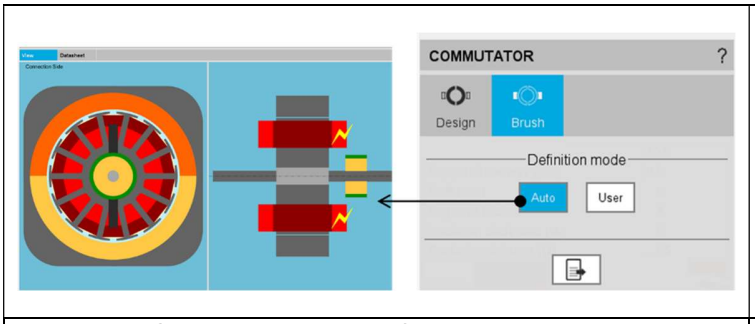
1.7.4 Commutator – Brush input parameters

Two definition modes can be chosen for brushes

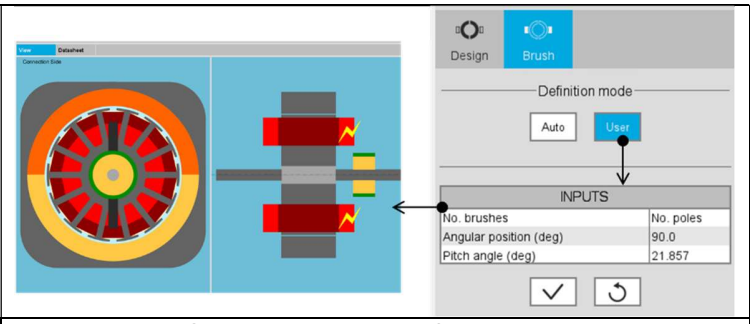
- Auto: Brushes dimensions and angular position are automatically calculated by FluxMotor to get the best fit with the defined winding. No input needed.
- User: Brushes dimensions and angular position are defined by the user.

The table below contains the brush input and their default values for “auto” mode.

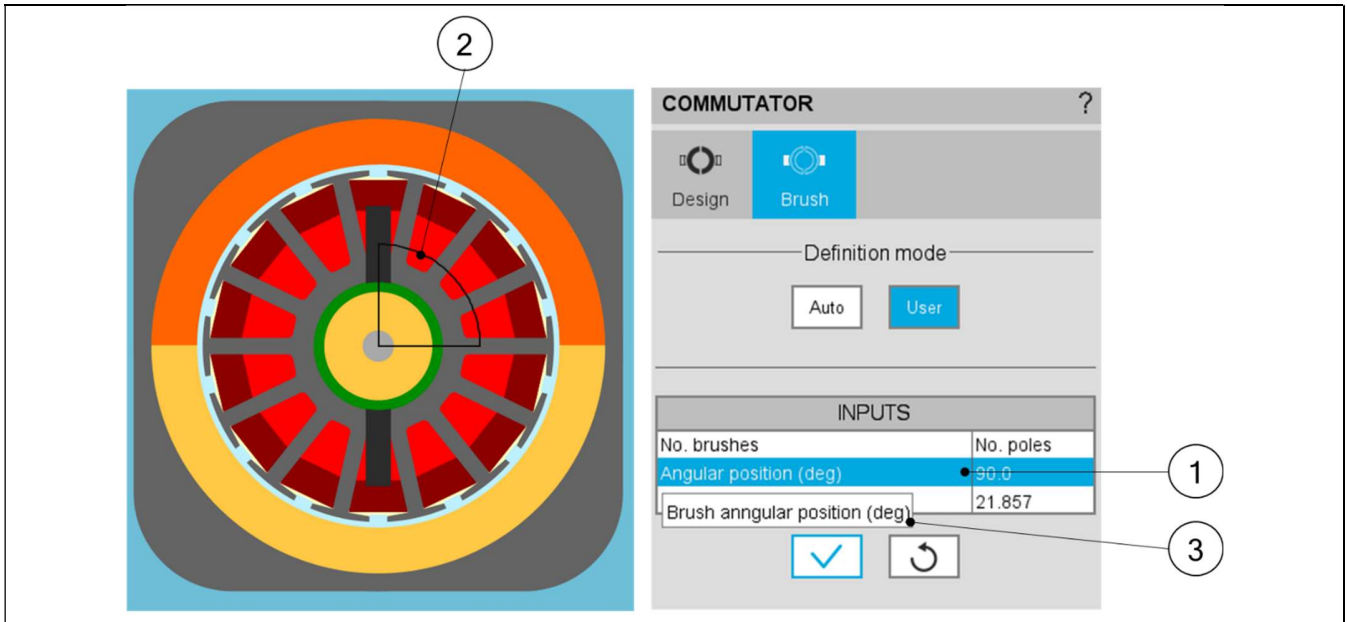
Label	Tooltip, note	Default value (auto mode)
Nº of brushes	Number of brushes. Only unblocked for wave winding	Number of poles
Angular position	Angular position of the reference brush (polarity +)	Center of a north pole (for lap winding) Center of a south pole (for wave winding)
Pitch angle	Pitch angle of a brush	0.85 times the segment commutator pitch for simplex winding (1.85 for duplex and 2.85 for triplex)



Commutator – Brush definition mode: None



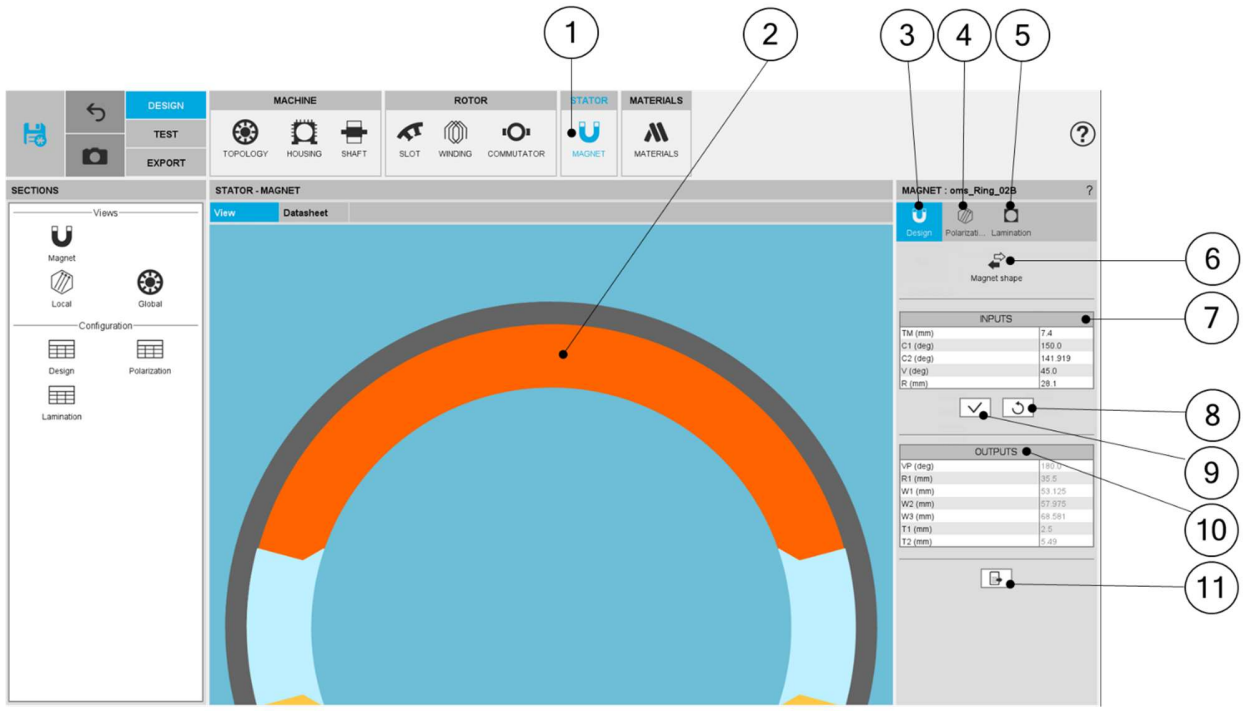
Commutator – Brush definition mode



Angles are illustrated in the visualization	
1	Select a parameter highlights it.
2	Select a parameter label displays the corresponding angle on the picture.
3	Select a parameter displays the corresponding tooltip which provides additional information

1.8 Magnet

1.8.1 Overview

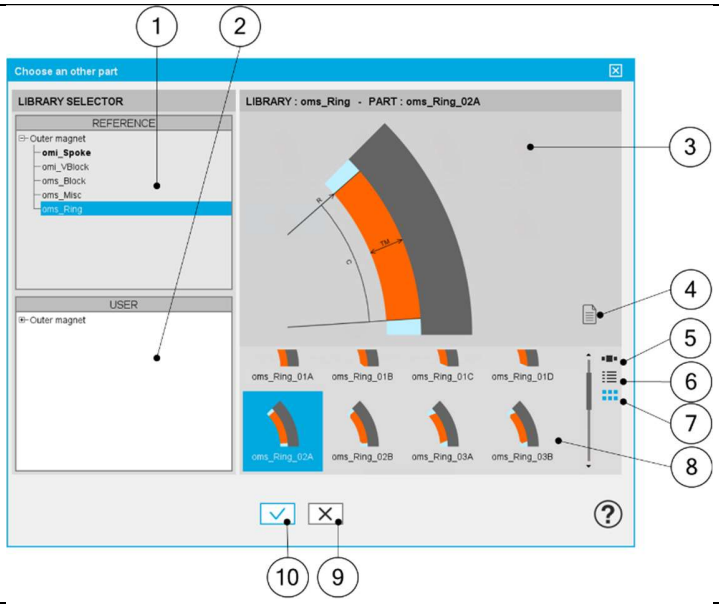


MAGNET design area	
1	Selection of the STATOR subset: MAGNET panel (Click on the icon MAGNET)
2	Visualization of the motor radial view to view the magnet topology and dimensions.
3	DESIGN tab indicates the tools to define the magnet topology and parameter values Note: By default, DESIGN tab is selected
4	POLARIZATION tab contains the tools to define the magnets polarization
5	LAMINATION tab contains the tools to define the lamination geometry
6	"Magnet shape" button allows accessing the magnet libraries to change the magnet topology. See additional information below.
7	User input parameter fields to enter the values.
8	Button to restore default input values.
9	Button to apply inputs. Pressing the “enter key” twice applies inputs too.
10	Output parameters (read only data) to complete the description of the topology.
11	Icon to export magnet data into *.txt or *.xlsx files.

1.8.2 Magnet - Design

1.8.2.1 Choose a magnet topology

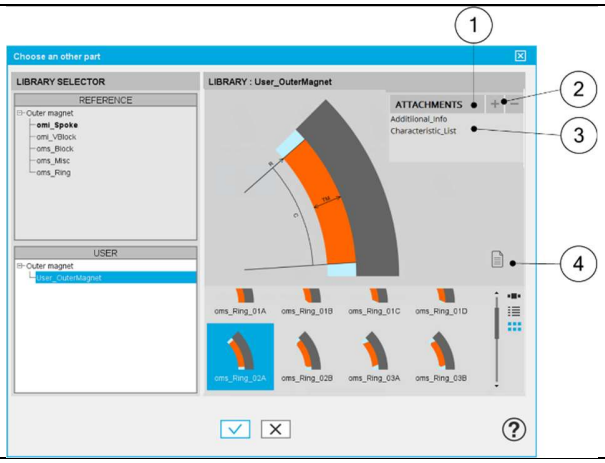
Clicking on the "Magnet shape" button opens a dialog box, allowing to access the magnet libraries.
It allows visualizing, comparing, choosing, and importing another magnet topology to modify in the current rotor design.



How to choose another magnet topology?

1	Visualization of reference libraries i.e. the libraries of magnet's topologies provided with Altair® FluxMotor®. Select them to view their content and choose the magnet among their content. See “Part Library” application for more information.
2	Visualization of user libraries. The default user library is “User_OuterMagnet”. See “Part Library” application for more information.
3	Area where the selected magnet is displayed (static picture) – Topology + dimension labels.
4	Button to visualize the list of documents attached to the part. See additional information below.
5	Button to display thumbnails as a slide show.
6	Button to display thumbnails as a list.
7	Button to display thumbnails as a matrix view of pictures.
8	Area to visualize all the topologies of magnets from the selected library (ref. 1).
9	Button to close the dialog box and come back to Motor Factory – DESIGN – Magnet area.
10	Button to choose and import the selected magnet to modify the current rotor design.

1.8.2.2 Attached documents – Additional information



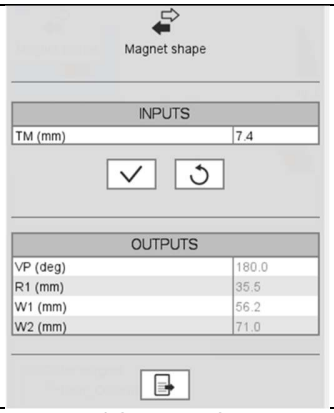
1	List of attached documents displays after clicking on button to display it (4).
2	“+” or “-“non-active buttons from “Motor Factory” See “Part Library” application for more information.
3	List of attached documents (if it exists) A double click on the selected document opens it. Documents can be added only from Part Library application. See “Part Library” application for more information.
4	Button to show or to hide the attached document list.

Visualization of attached documents

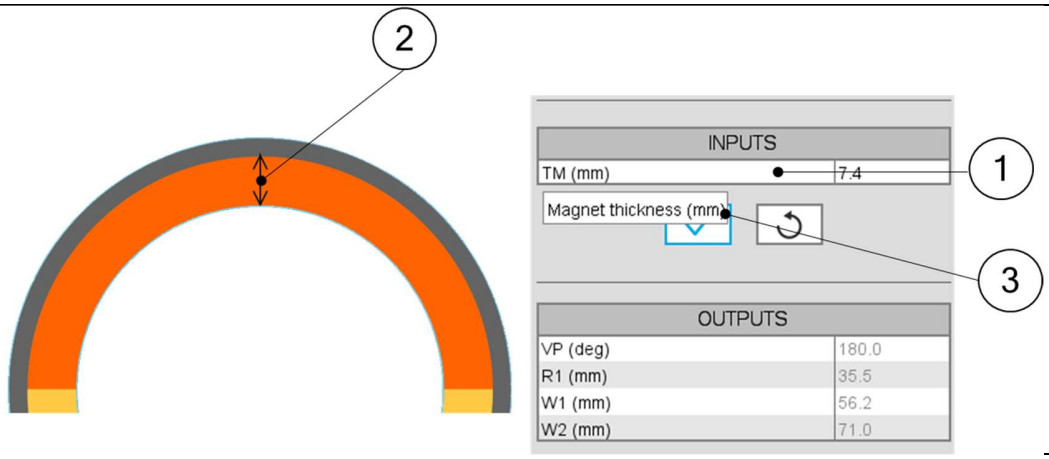
1.8.2.3 Inputs / Outputs

Specific inputs and outputs are considered for magnet topology.
The relevance of input parameter values can be evaluated by using “Part Factory” application.
See “Part Factory” application for more information.

Outputs are read only data. They complete the description of the topology.



Inputs / Outputs of magnet

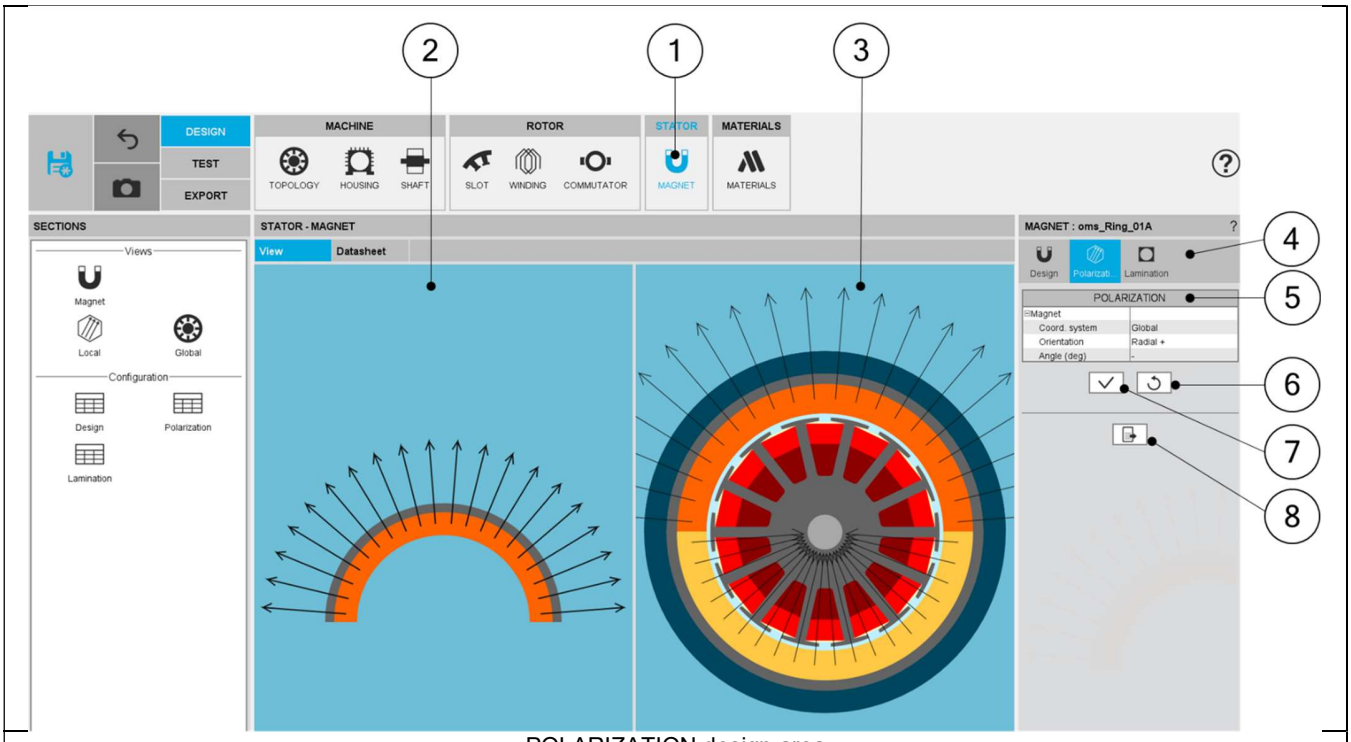


Inputs / Outputs of magnet

1	Selection of a parameter label highlights it.
2	Selection of a parameter label displays the corresponding arrow on the picture.
3	Selection of a parameter label displays the corresponding tooltip which completes information about the parameter.

1.8.3 Magnet - Polarization

1.8.3.1 Overview



POLARIZATION design area

1	Selection of the STATOR subset: POLARIZATION panel (Click on the icon POLARIZATION)
2	Visualization of the polarization on one pole.
3	Visualization of the polarization on the whole machine.
4	Tabs to navigate through the different MAGNET menus
5	Area to choose the polarization strategy. Five types of orientation and two coordinate systems and angle are available. See additional information below.
6	Button to restore default input values. Default polarization is defined in Part Factory application via Excel file. See “Part Factory” application for more information.
7	Button to Apply inputs. Pressing the enter key twice applies inputs too.
8	Icon to export polarization data into *.txt or *.xlsx files.

1.8.3.2 Choice of polarization

Polarization coordinate system

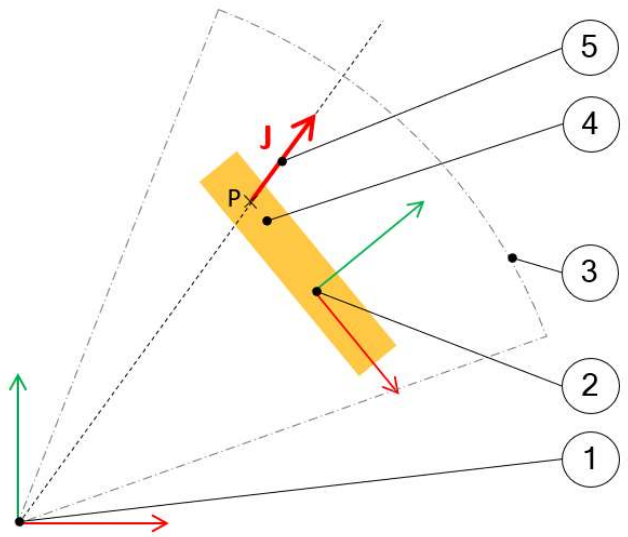
Two coordinate systems are available:
A “**Global**” polarization coordinate system: The origin is positioned at the rotor center.
A “**Local**” polarization coordinate system which is specific to each considered magnet topology.
Note: The reference axis (X-axis for Cartesian coordinate system) has a red color.

Polarization orientation

Five strategies of polarization are proposed:

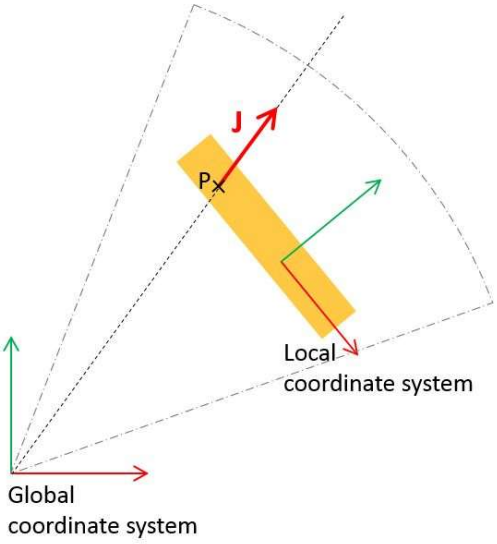
- Direction
- Radial +, Radial –
- Orthoradial +, Orthoradial –

1) Polarization orientation illustrations

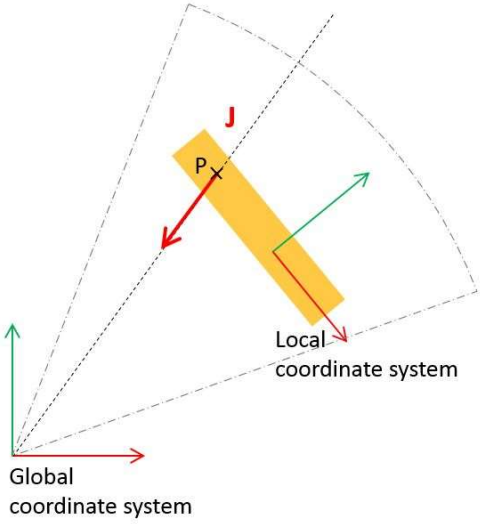


1	Global coordinate system. The origin is positioned at the rotor center. The reference axis is the X-axis. Its color is red.
2	Local coordinate system. Its location is defined for each magnet topology. See “Part Factory” application for more information. The reference axis is the X-axis. Its color is red.
3	Borders of part sector in which magnet topology is defined.
4	Magnet in which a point P is considered to illustrate the polarization orientation.
5	Polarization of the magnet considered at any point P.

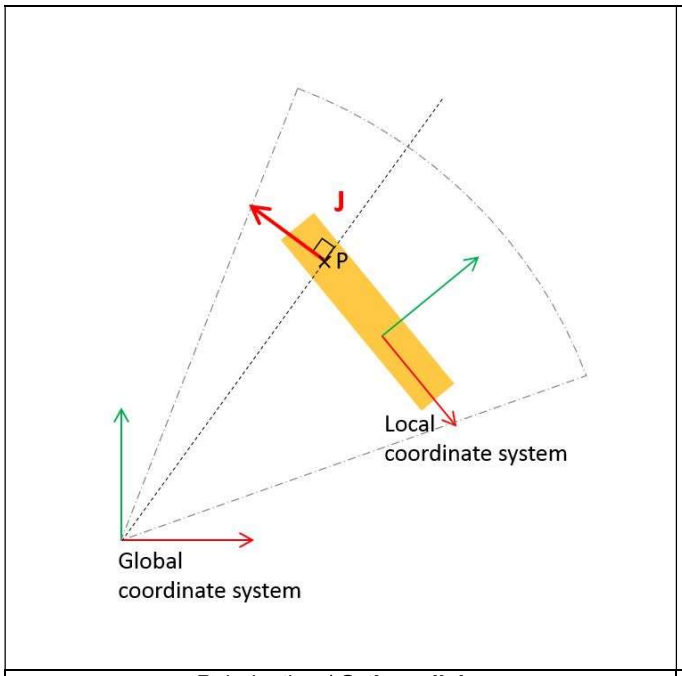
Legend of pictures to illustrate the magnet polarization orientation



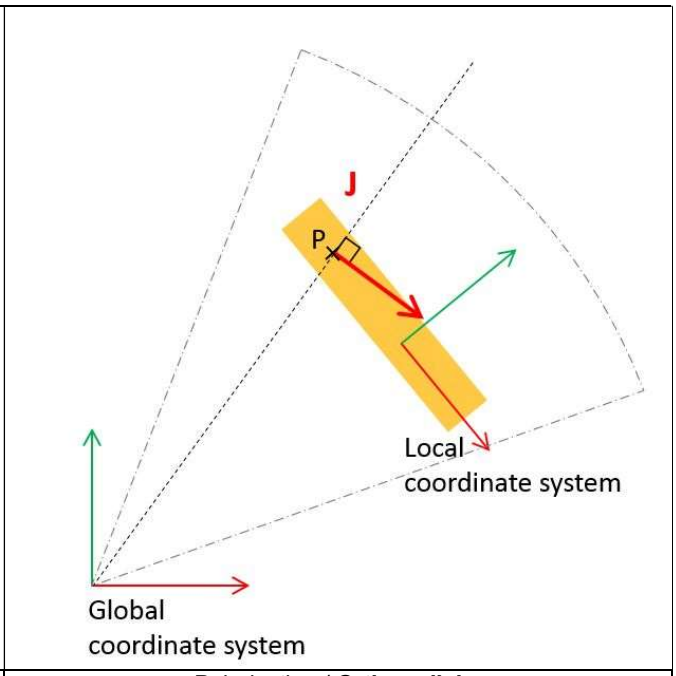
Polarization / **Radial +**
Global coordinate system



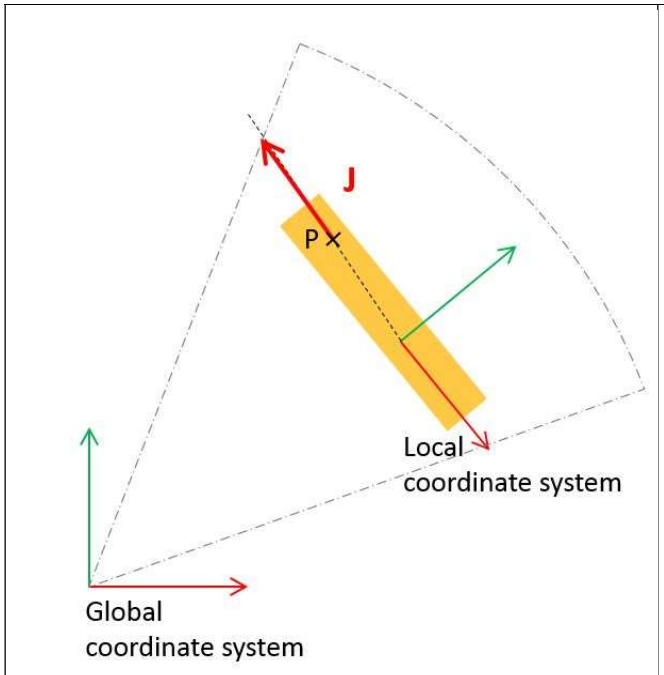
Polarization / **Radial –**
Global coordinate system



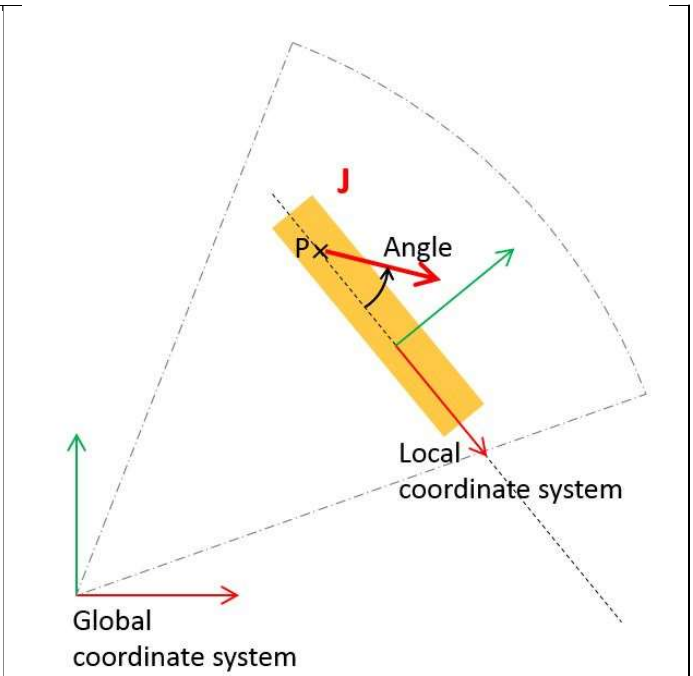
Polarization / **Orthoradial +**
Global coordinate system



Polarization / **Orthoradial –**
Global coordinate system



Polarization / **Radial +**
Local coordinate system

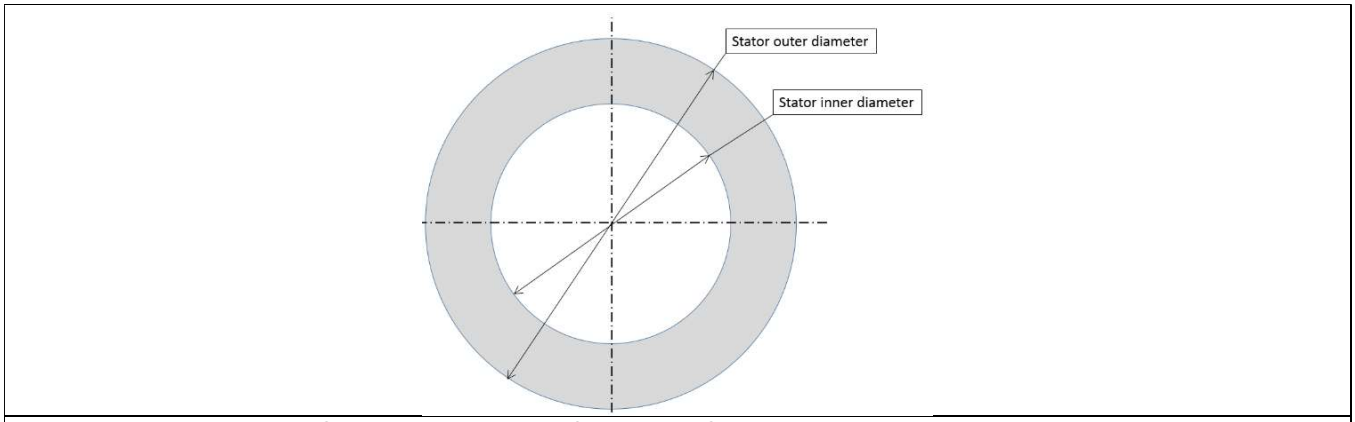


Polarization / **Direction + Angle**
Local coordinate system

1.8.4 Magnet – Lamination

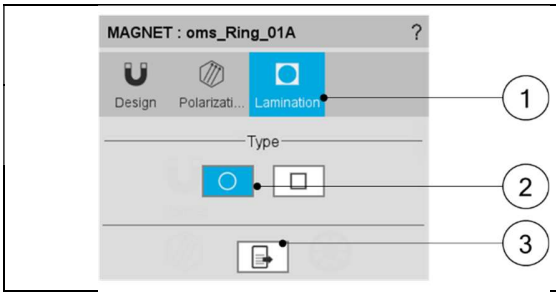
1.8.4.1 Overview

The tools available in the lamination tab allow in defining the outer shape of the lamination.
Three choices are available to define the lamination topology: Circular or Square.
By default, the outer shape of the lamination is defined by considering the outer diameter of the stator (defined in structural data).
In that case outer shape of lamination is circular without extensions. Outer dimensions of lamination are indicated in general data (structural data part). See illustration below.



Original structural data of the stator: Outer and inner stator diameters

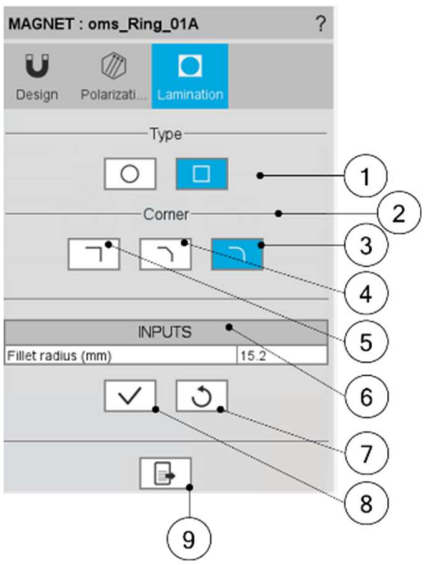
1.8.4.2 Circular shape lamination



1	Choice of lamination tab
2	Choice of a circular shape lamination
3	Icon to export lamination data into *.txt or *.xlsx files.

1.8.4.3 Square shape lamination

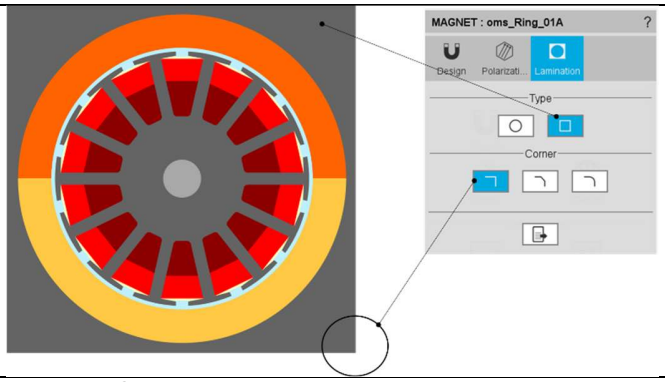
1) Main inputs



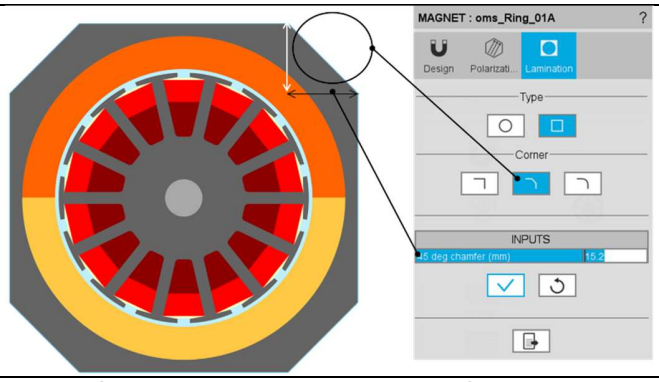
1	Choice of a square shape lamination.
2	Corner type available (Right, Chamfer, Fillet).
3	Button to select “fillet” type corner.
4	Button to select “chamfer” type corner.
5	Button to select “right” type corner.
6	User input parameters (for the corner types that need it)
7	Button to restore default input values.
8	Button to apply inputs. Pressing the enter key twice applies inputs too.
9	Icon to export lamination data into *.txt or *.xlsx files.

Dialog box to define the square shape lamination

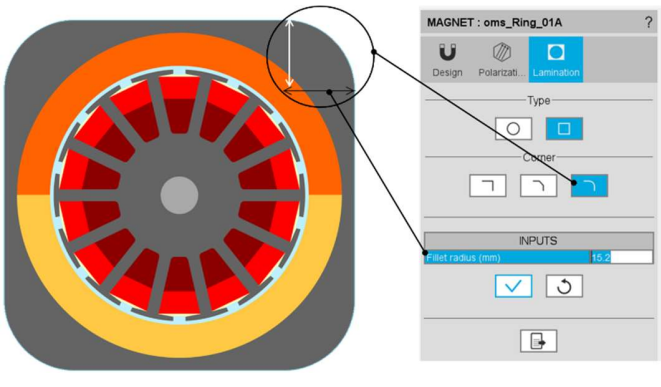
2) Description of the different kinds of square shape lamination available



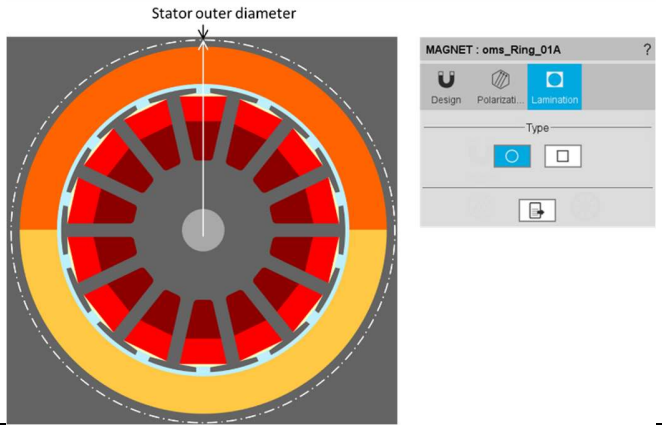
Square shape lamination with right corner



Square shape lamination with chamfer corner



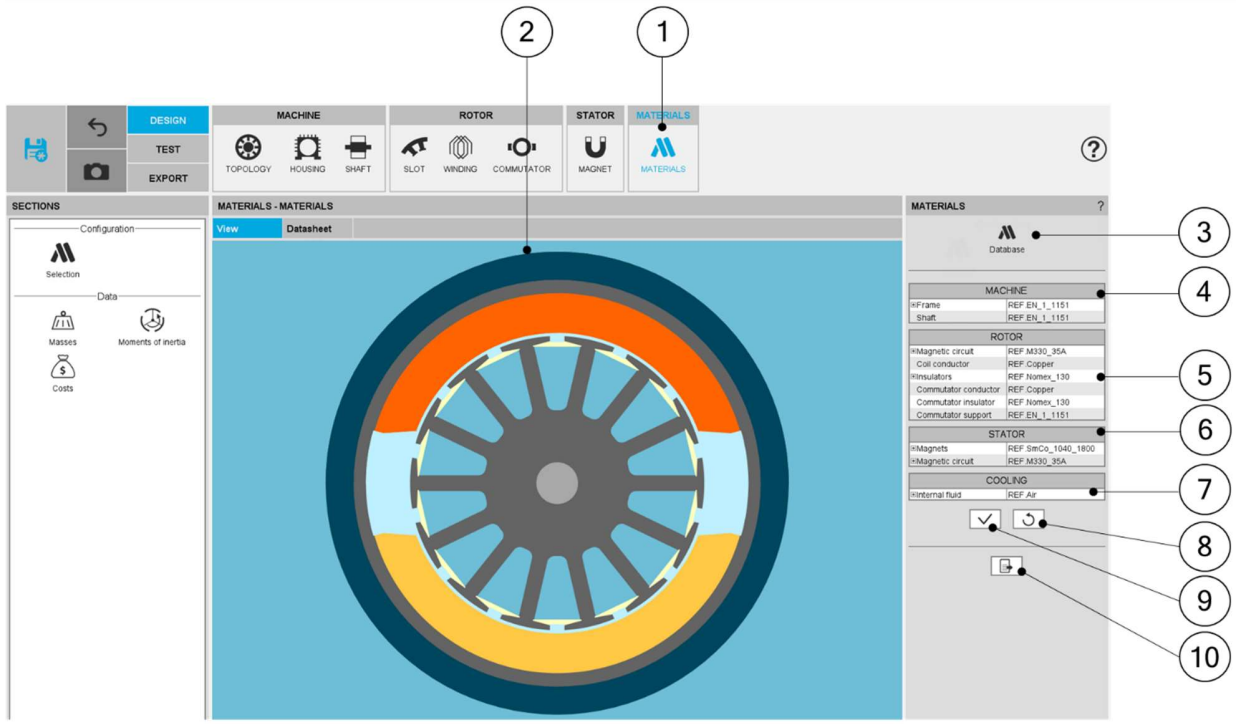
Square shape lamination with fillet corner
Setting of the lamination fillet radius



Square shape lamination with right corner
See the link with stator outer diameter

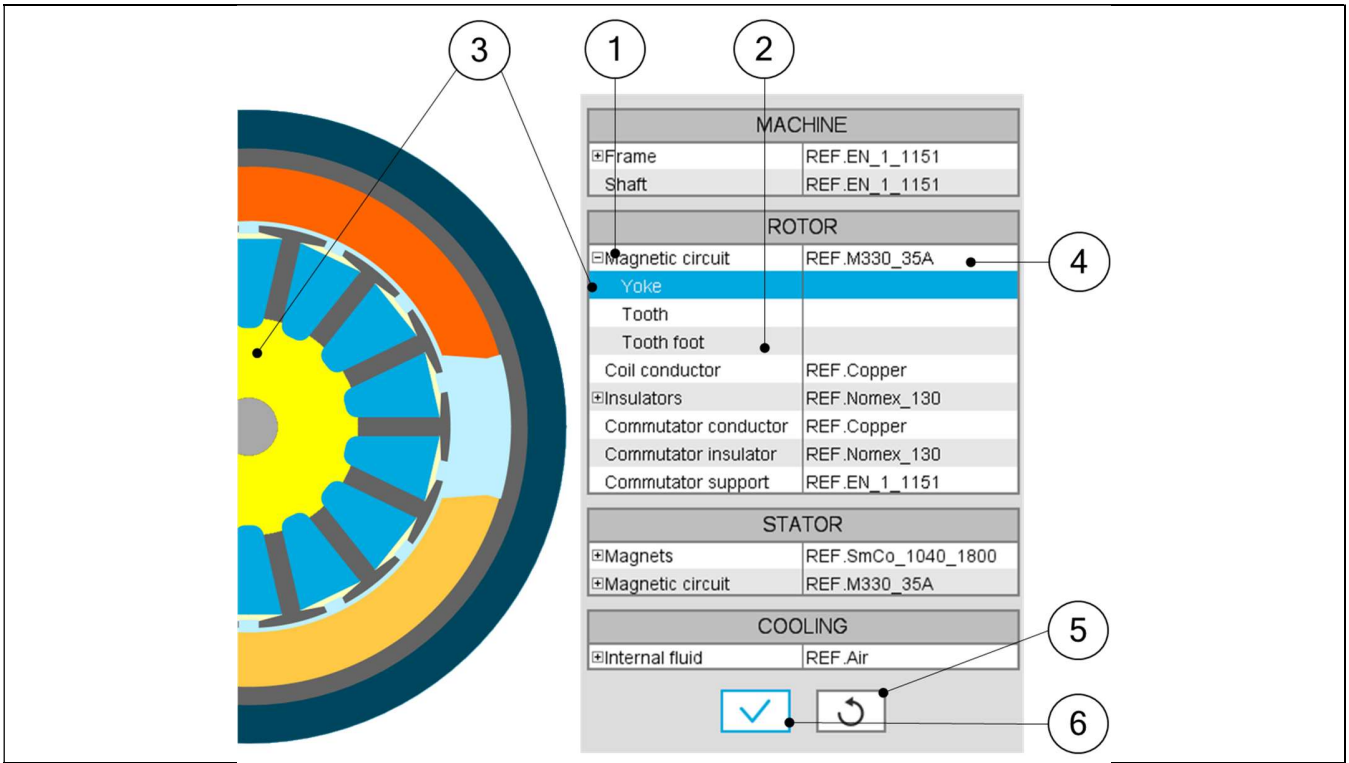
1.9 Materials

1.9.1 Overview



MATERIALS design area	
1	Selection of the Material subset: MATERIALS panel (Click on the icon MATERIALS)
2	Visualization of the machine regions.
3	Direct access to open material manager. It allows seeing properties of materials.
4	Area to assign materials to machine regions (frame, shaft). See additional information below.
5	Area to assign materials to rotor regions (magnetic circuit, coil conductor, insulation). See additional information below.
6	Area to assign materials to Stator regions (magnetic circuit, magnets). See additional information below.
7	Area to assign materials to Cooling fluids (internal fluid). See additional information below.
8	Button to restore default materials. Default materials are those defined as favorite materials in Material manager. See “Materials” application for more information.
9	Button to validate assignment of materials. Pressing the Enter key twice applies inputs too.
10	Icon to export material data into *.txt or *.xlsx files.

1.9.2 How to assign materials – Example for rotor lamination



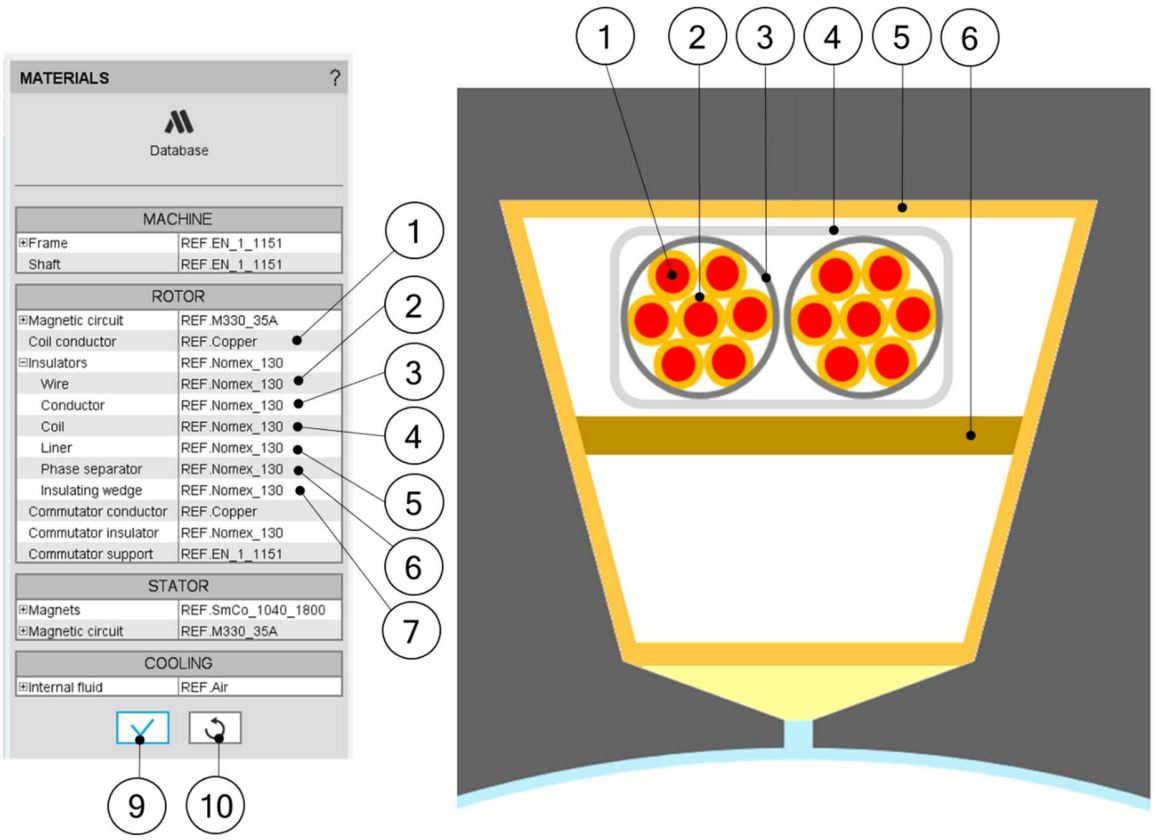
Assign materials to the rotor magnetic circuit	
1	Expand the section dedicated to the magnetic circuit. Different materials (LAMINATION type or SOLID type) can be assigned to it.
2	The magnetic circuit can be subdivided into several parts. (Yoke, tooth and tooth foot).
3	By selecting a region name (Yoke for example) the corresponding face region is highlighted.
4	Expand the material list to choose a material to assign to the magnetic circuit. Only one material can be assigned to the rotor magnetic circuit. In our example it is not possible to assign different materials to sub regions like yoke and tooth.
5	Button to restore default materials. Default materials are those defined as favorite materials in Material manager. See “Materials” application for more information.
6	Button to validate assignment of materials. Pressing the enter key twice applies inputs too.

For more information about the rules leading to the building of parts like slots, please refer to Part Factory application.

1.9.3 Materials for the winding

All the materials are selected in the material database.

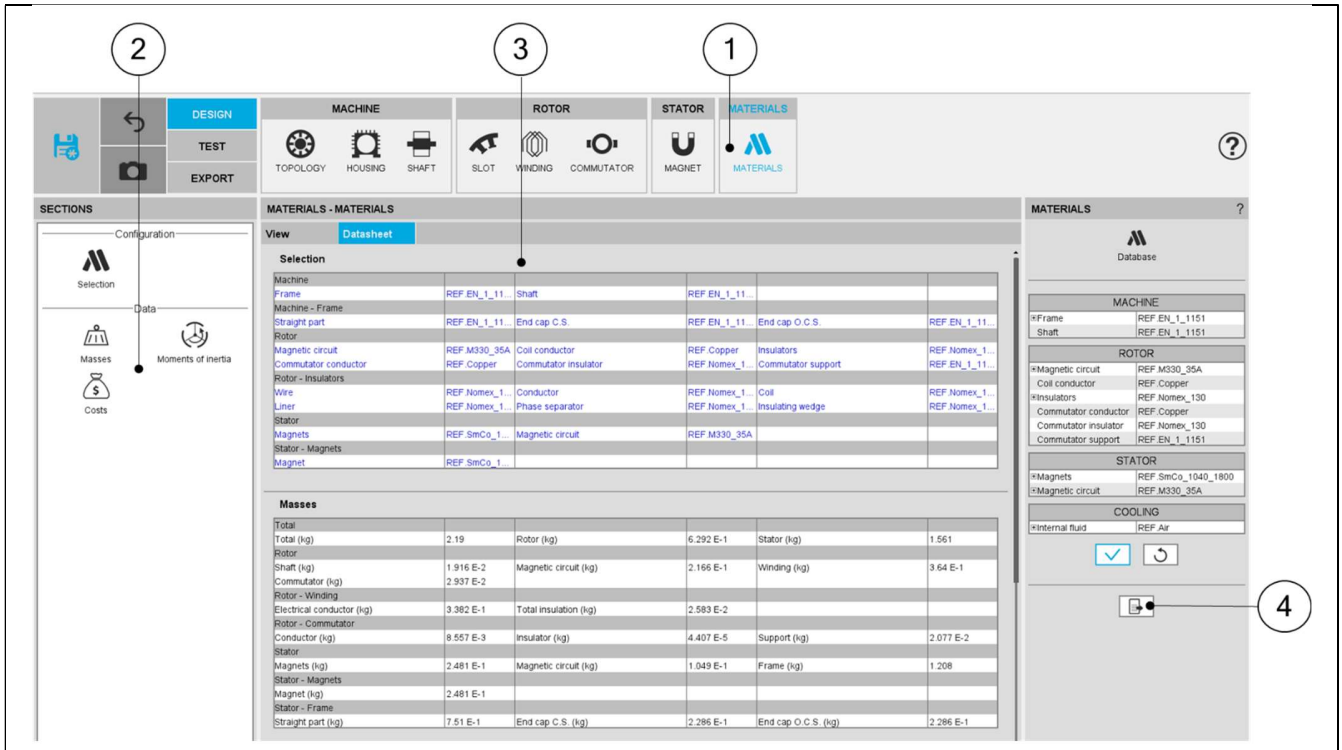
Conductor materials are selected in the “Electrical Conductor” type material family.
Insulator materials are selected in the “Electrical Insulator” type material family.
Thicknesses of insulations are defined inside the winding settings panel – COIL tab.
Insulation materials are considered only if a corresponding thickness is defined.



Building the winding architecture – **Choice of winding MATERIALS -** Conductor and insulation

1	Conductor materials
2	Wire insulation
3	Conductor insulation
4	Coil insulation
5	Liner
6	Phase separator
7	Insulating wedge
8	Material used for encapsulating the end-windings (potting)
9	Button to validate assignment of materials. Pressing the enter key twice applies inputs too.
10	Button to restore default materials. Default materials are those defined as favorite materials in Material database. See “Materials” application for more information.
*	Insulators: If all the above choices correspond to the same material, then the corresponding material name is written in the insulators field. Otherwise “Diversified” is written in the insulators field which means there are different insulating materials.

1.9.4 Material datasheet



MATERIALS design area

1	Selection of the MATERIALS panel (Click on the icon MATERIALS)
2	Shortcuts to reach material datasheet sections
3	Material datasheet where materials, masses, moment of inertia and costs are displayed
4	Icon to export stator material data into *.txt or *.xlsx files.