Altair® Flux®

Translating Motion Tutorial - 3D Technical Example

Updated: 11/08/2022

Foreword

Please read before starting this document

Description of the example

The goal of this technical example is to demonstrate the ability and advantage of Flux for the simulation of trident-shaped contactor Schneider Electric computation problems. This document contains the general steps and all the data needed to describe the different simulations.

To begin

This example is designed for the user who is already familiar with the basic functions of Flux software.

For beginner users, please report to the “Flux Starting Guide” opened automatically by the supervisor. (If not opened, please open it by clicking on the button “?” on the top right of the supervisor). The interface contains videos, which helps the beginners while using Flux for the first time.

Support files included…

To view the completed phases of the example project, the user will find the `.py` files, including the geometry, physics and post-processing descriptions. The `.py` files corresponding to the different study cases in this example are available in the folder:

`…\DocExamples\Examples3D\Tutorial_Technical\TranslatingMotion\`

Supplied files are command files written in Pyflux language. The user can launch them in order to automatically produce the Flux projects for each case.

> **Note:** *.py files are launched by accessing* ***Project*** *>* ***Command file*** *from the Flux drop down menu.*

Files

Supplied files	Contents	Flux file obtained after launchnig the .py file
`CASE1/buildGeomesh.py`	Geometry and mesh	`CASE1/Geomesh.FLU`
`CASE1/buildPhys.py`	Physics	`CASE1/BuiltPhys.FLU`
`CASE1/solving.py`	Solving process	`CASE1/Solved.FLU`
`CASE1/postprocessing.py`	Post processing	`CASE1/Postprocessed.FLU`
`CASE2/TESTCASE_INI.FLU`	Initial Flux project	
`CASE2/buildPhys.py`	Physics	`CASE2/BuiltPhys.FLU`
`CASE2/solving.py`	Solving process	`CASE2/solved.FLU`

Supplied files	Contents	Flux file obtained after launchnig the .py file
`CASE2/postprocessing.py`	Post processing	`CASE2/postprocessed.FLU`

Note: Some directories may contain a main.py enabling the launch of the command files. Flux files are ready to be meshed and then solved.

Contents

General information

1

This chapter covers the following:

Introduction

The aim of this tutorial is the computation of magnetic field and mechanical quantities for a trident-shaped contactor Schneider Electric.

This chapter describes the device, explains the strategies used for geometry construction, mesh generation and physical description and introduces the theoretical aspects of the magneto-mechanical coupling and kinematic models.

1.1 Overview

Introduction

This section is an overview of the sample problem. It contains a brief description of the device and studied cases.

Contents

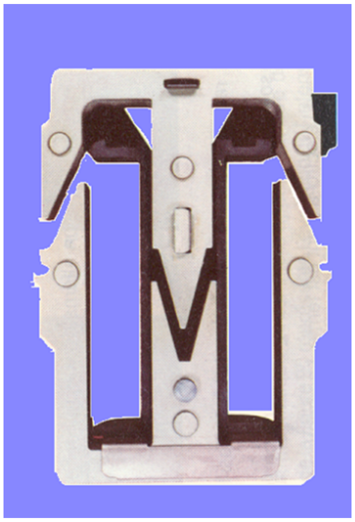
This part contains the following:

- Foreword
- Description of the studied device
- Studied cases

1.1.1 Foreword

Contactor

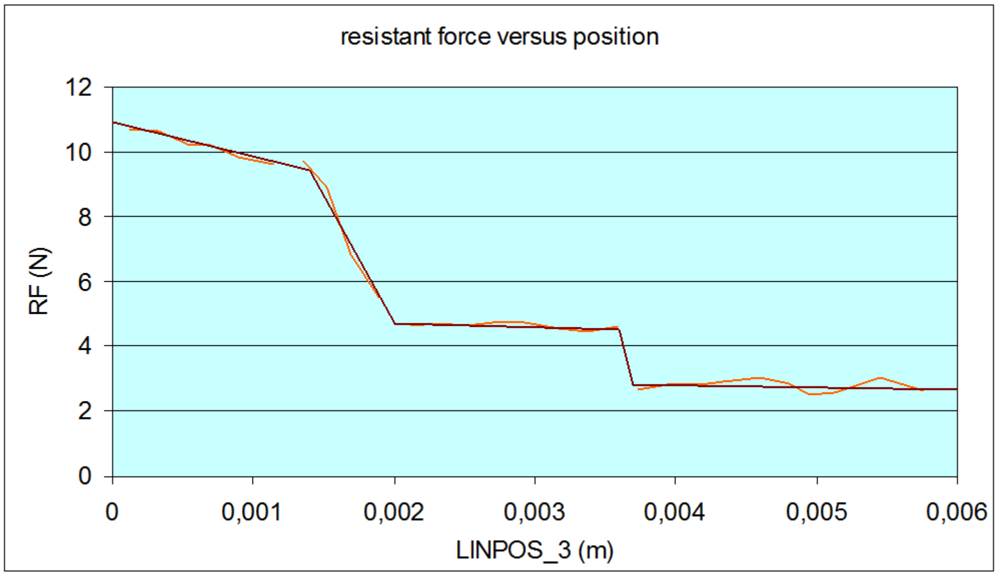
The study of a trident-shaped contactor Schneider Electric is carried out in this tutorial. Planar view of the trident is presented in the figure below.



Measurements used in the study

The contactor has been fully analyzed in the Schneider Electric laboratories, and the kinematic properties of modeled device for case 2 are based on these measurements.

The kinematic properties of the device are defined using its resistant force. In the graph below the model of the resistant force is presented by the black curve, while the red curve shows the measurements done by the Schneider Electric Company.



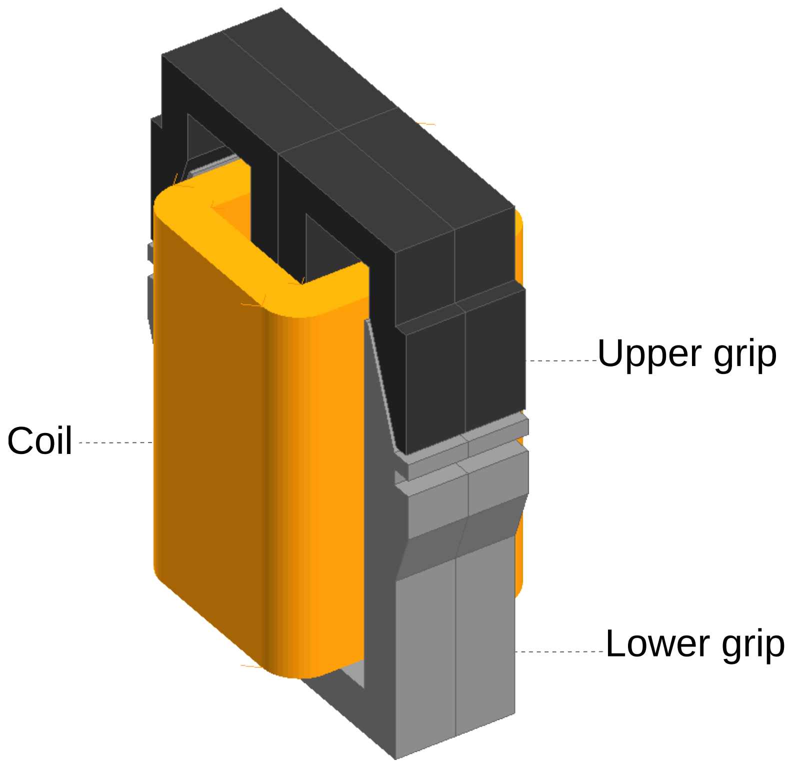
1.1.2 Description of the studied device

Studied device

The device to be analyzed is a contactor – the trident – that serves as a switch to start an electric motor.

The studied device, represented in the figure below, includes the following elements:

- a lower grip – ferromagnetic (laminated) fixed part
- an upper grip – ferromagnetic (laminated) moving part assembled on springs
- a coil placed around the central tooth



Operating principle

When current passes through the coil, a magnetic field is produced which attracts the ferrous objects, in this case the moving core of the contactor is attracted to the stationary core. Since there is an air gap initially, the coil draws more current initially until the cores meet and reduce the gap, increasing the inductive impedance of the circuit.

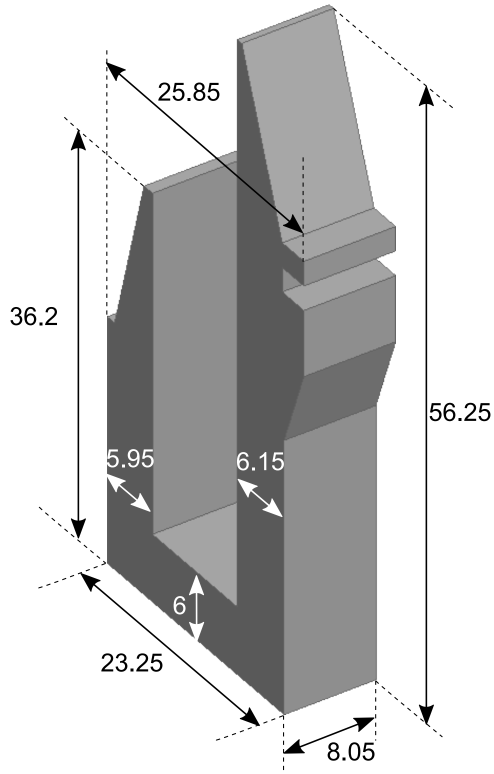
The different phases of the process are the following:

- the coil is supplied by 24-volt power voltage source
- under the effect of the magnetic force, the upper part moves to make contact with the lower one
- then the switch is on

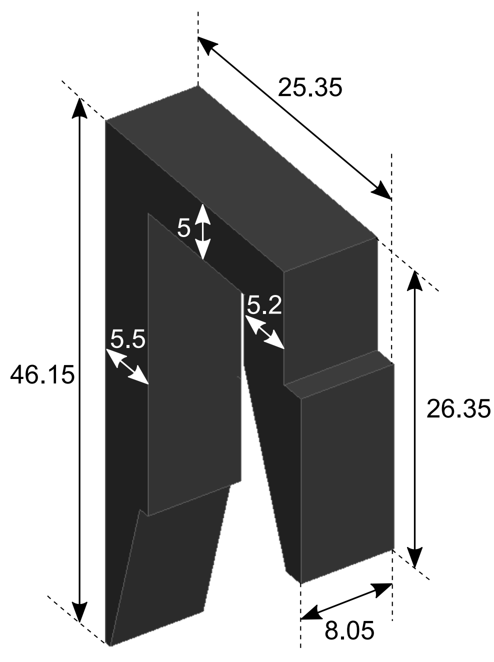
Geometry

The trident is composed of two main parts – fixed and moving. Only a quarter of the device is modeled because of the presence of two symmetries.

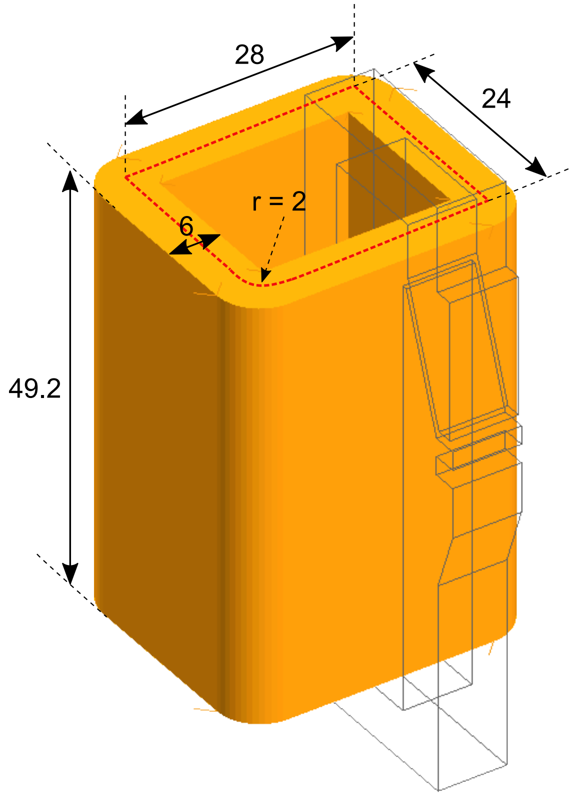
The dimensions of the modeled fixed part – lower grip – are presented in the figure below:



The dimensions of the modeled moving part – upper grip – are presented in the figure below.



The dimensions of the modeled coil are presented in the figure below.



Material

The trident is made of ferromagnetic strip iron material, which prevents eddy currents from appearing.

Source

The source of a magnetic field is the current flowing through the coil.

1.1.3 Studied cases

Studied cases

Two cases are carried out:

- Case 1: study with the multi-static model (different linear positions)
- Case 2: study with the coupled load model (with circuit coupling)

Case 1

The first case is a study using the multi-static kinematic model (Magneto Static application).

In this case (multi-static kinematic model), the moving part of the device can take various positions fixed arbitrarily.

We are interested in the computation of the magnetic field for arbitrarily chosen positions of the mobile grip.

With this model it is possible to evaluate the force acting on the fixed grip at different positions.

Case 2

The second case is a parametric study using the coupled load kinematic model (Transient Magnetic application).

In this case (coupled load kinematic model), a resistant force is exerted on the moving part of the device by means of a system of return springs; the coil is supplied by an external electric circuit (voltage source).

The advantage of this model is to study the time variation of the position and speed of the mobile grip and the time variation of the electromagnetic force acting on the mobile grip.

1.2 Strategy to build the Flux project

Introduction

This section explains the strategies of the geometry, mesh and physical description.

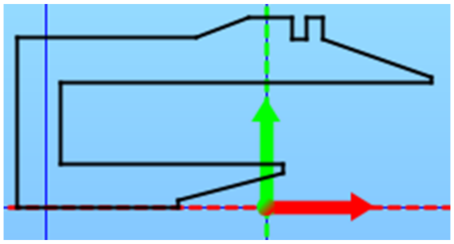
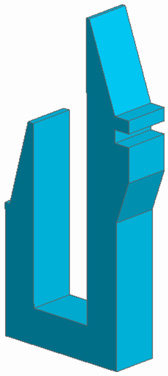
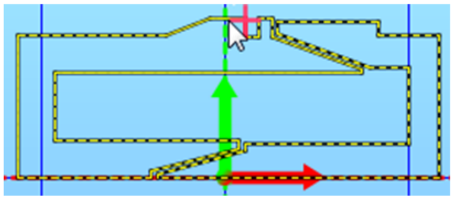
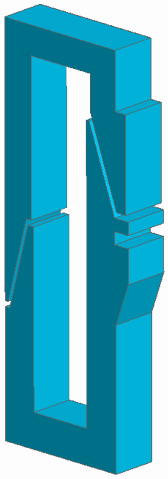
Contents

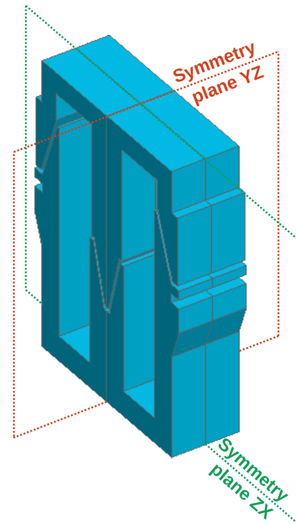
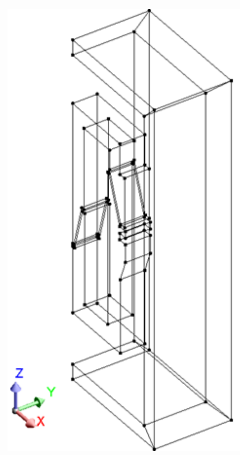
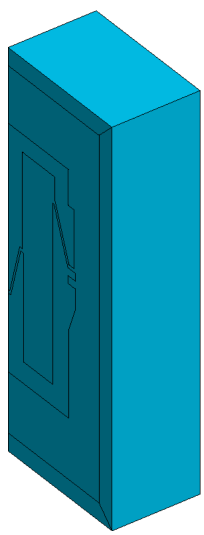
This section contains the following topics:

1.2.1 Main stages for geometry description

Outline

An outline of the geometry building process presented in the table below:

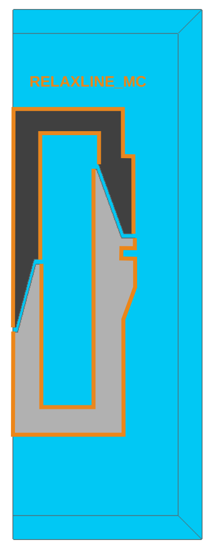
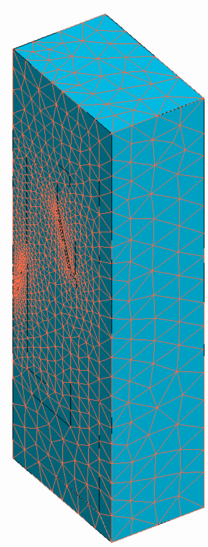
Stage	Description	
1	Creation of the lower grid using the sketch context	
2	Extrusion of the shape in the modeler context	
3	Creation of the upper grid shape using a sketch	
4	Extrusion of the shape in the modeler context	

Stage	Description	
5	Creation of symmetries to model a quarter of the trident	
6	Creation of an infinite box to impose a zero magnetic field at infinity	
7	Closing of the domain and creation of faces and volumes	

1.2.2 Main stages for mesh generation

Outline

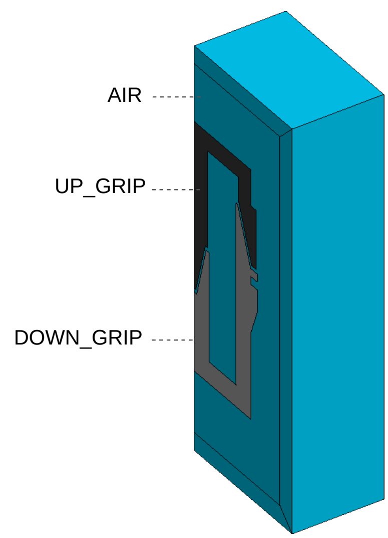
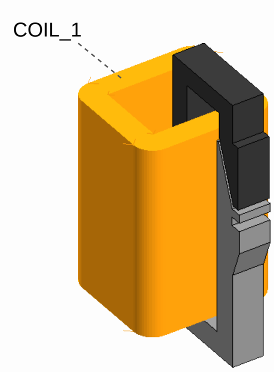
An outline of the mesh generating process presented in the table below:

Stage	Description	
1	Meshing the device and analyze of the mesh	Mesh with the default settings of **AIDED MESH**. It is possible to improve the mesh quality
2	Modification of the **AIDED MESH**	Reduce the relaxation values to low (r=0.25)
3	Creation and assignment of a local line relaxation (r=0.1) to control the density in an automatic mesh	
4	Meshing: • meshing lines • meshing faces • meshing volumes • generating 2^{nd} order elements	

1.2.3 Main stages for physical description

Outline

An outline of the physical description process presented in the table below:

Stage	Description	
1	Definition of the application	Magneto Static 3D
2	Definition of physical aspects of the symmetry	Tangent magnetic field
3	Creation of 3 mechanical sets	• **FIXED_PART** • **COMPRESSIBLE_PART** • **TRANSLATION_PART**
4	Creation of a material	• **FESI** – material with a nonlinear **B(H)** characteristic
5	Creation and assignment of volume regions	
6	Creation of sources	

1.3 Kinematics: Theoretical aspects

Introduction

The kinematic module allows us to take into consideration the displacement of a moving part of a device due to:

- mechanical forces from springs, friction, gravity, etc.,
- and electromagnetic forces, generated by magnets, coils, etc.

This module solves problems with **magneto-mechanical coupling** or performs **studies with kinematic coupling**.

Contents

This section contains the following:

Reading advice

The theoretical aspects of kinematic coupling are presented in the User’s guide (see “Kinematic coupling: principles”)

1.3.1 Magneto-mechanical coupling

Magneto mechanical coupling

The **magneto-mechanical coupling** takes into account the magnetic and kinematic aspects of a problem. The magnetic aspect is characterized by Maxwell equations and the kinematic one by the fundamental equations of dynamics in translating or rotating motion.

Fundamental dynamics equation in translating motion

The dynamics of a body in translating motion is expressed by the fundamental equation:

$$m\frac{\partial^2 y}{\partial t^2} = \Sigma\vec{F}_{ext} \Rightarrow m\ddot{y} = F_{em} - F_r$$

where:

- m is the mass of the moving body
- y is the instantaneous body position and $\ddot{y}$ is its linear acceleration
- Fr is the resistant mechanical force acting on the body
- F_{em} is the electromagnetic force acting on the body

Solving principle

The **magneto-mechanical coupling** is a weak coupling between the electromagnetic and kinematic aspects of the problem. To solve this type of problem, we apply a four-stage procedure, as outlined below. At each time step, the electromagnetic aspect is analyzed first and then the kinematic one.

The algorithm of this method can be summarized as follows:

Stage	Description
1	Solve the Maxwell equations and compute the electromagnetic force or torque acting on the moving part for a given relative position between the moving and fixed parts of the device
2	Solve the equation of moving part dynamics, compute the acceleration and speed of the moving part during a time step and compute the new position of the moving part for the next time step.
3	Move the moving part to the new position and (if necessary) re-mesh the displacement area.
4	Return to stage 1 for the next computation step

Additional notes

The electromagnetic force and the magnetic torque acting on the moving part are computed by the virtual work method.

The mechanical force or torque acting on the moving part is an input data of the problem, entered by the user.

1.3.2 Kinematic models

Introduction

The analysis of the magnetic field in devices with moving and fixed parts can be performed with three **kinematic models** provided by Flux.

Multi-static kinematic model

In the **multi-static** kinematic model, the movable part of the device is not moving.

The computation of the electromagnetic field is carried out for various arbitrary relative positions of moving and fixed parts. This model performs a set of **magneto-static computations** ($\partial / \partial t = 0$ in Maxwell equations), and does not take into consideration the dynamics equation. This model is equivalent to a parametrized study where the position of the moving part is a parameter.

Imposed speed kinematic model

In the **imposed speed** kinematic model, the movable part is considered as moving at a constant velocity with respect to the fixed part.

The computation of the electromagnetic field is carried out for the different positions defined by the imposed speed of the moving part. As in the previous (multi-static) kinematic model, the dynamics equation is not considered.

In the **imposed speed** kinematic model, the physical application used is the Transient Magnetic physical application. In this case, the Maxwell equations consider the time dependence of the electromagnetic field ($\partial / \partial t \neq 0$).

Important notes

The imposed speed model and the multi static model offer the same results if the sources of the electromagnetic field are constant: constant current sources, permanent magnets, etc. and that there is no coupling circuit.

On the other hand, the results of these two models are different under the following conditions:

- time-varying sources: varying current sources (directly in the Flux project or through a circuit coupling), etc.
- conductive regions, where eddy currents occur, etc.

Coupled load kinematic model

In the **coupled load** kinematic model, the moving part drives an external device that represents the mechanical load of the studied device.

This is the model where the **magneto-mechanical coupling** is considered, that is to say, both the magnetic aspect and the kinematic aspect of a problem.

The physical application used is the **Transient Magnetic** application.

1.3.3 Effect of displacement on the geometry description and re-meshing

Mechanical set

To describe motion in the finite element domain, the regions are assigned to mechanical sets. A mechanical set is a set of regions and coils that have the same displacement characteristics.

A mechanical set of ...	includes the regions corresponding to...
fixed type	fixed parts
moving type	mobile parts
compressible type	the area of air in which the mobile part is moving

Displacement of the moving part and re-meshing

The displacement of the moving part determines the modification of the geometry of the modeled device. Consequently, the computation domain must be re-meshed at each time step.

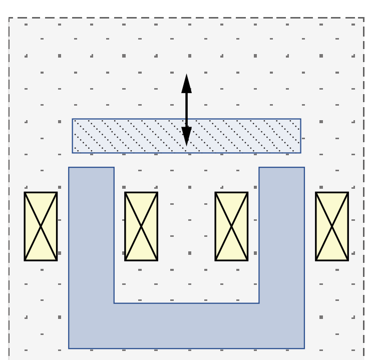
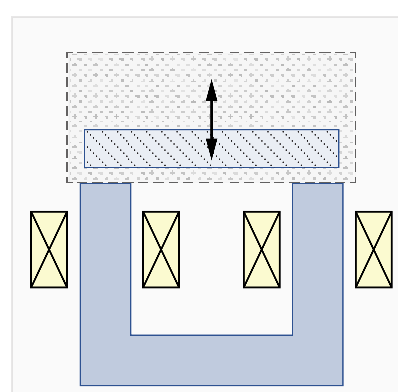
There are different re-meshing techniques depending on the type of motion and on the presence or absence of an air-compressible area.

Technique used

The technique used consists in dissociating the different parts and re-meshing only the compressible part; the fixed and moving parts are not re-meshed.

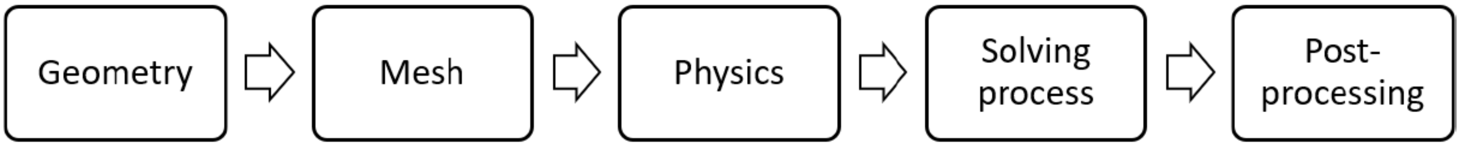
Compressible mechanical set

Different methods of defining the compressible area are presented in the table below. The first case corresponds to the most common one.

	1st case	2nd case
Geometry scheme		

	1st case	**2nd case**
Compressible mechanical set	Maximum area, corresponding to the air region	Minimum area, in which the moving part moves
Advantage	No need to create a specific region	Reduced area to re-mesh → reduced requirements for mesh storage
Disadvantage	Larger area to re-mesh → larger requirements for mesh storage	Requires creation of a specific region

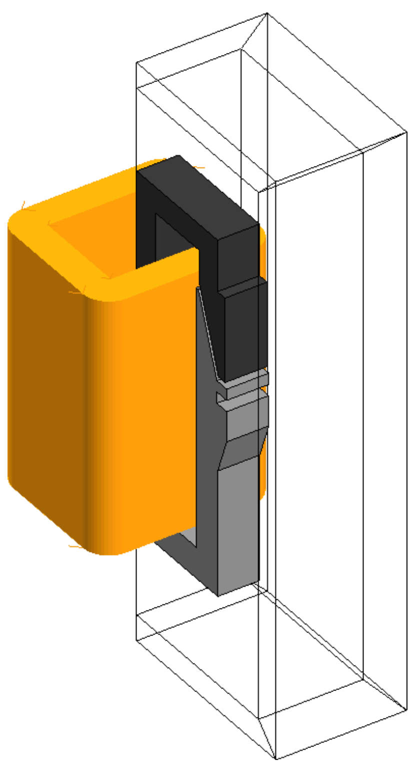
Construction of the Flux project 2



This chapter covers the following:

Introduction

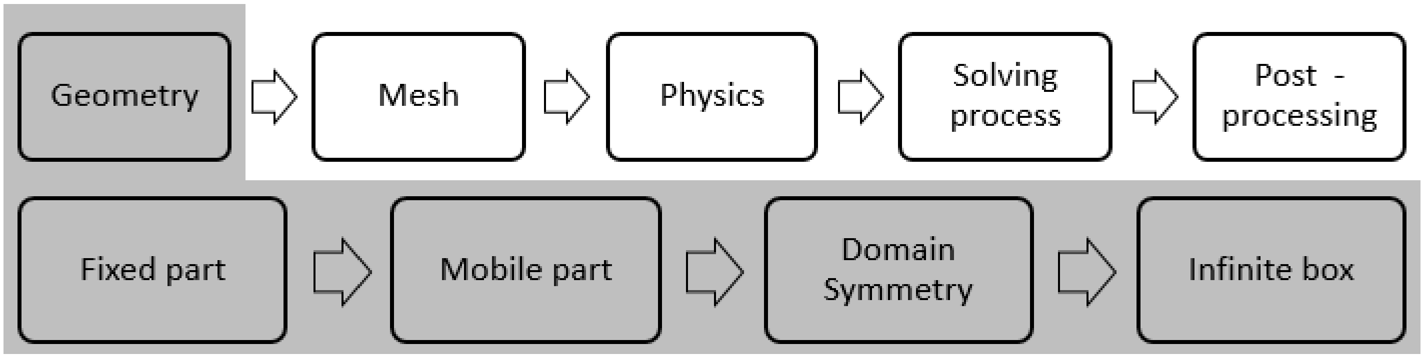
This chapter describes the main steps of the geometry construction, mesh generation and physical description of the trident.



Project name

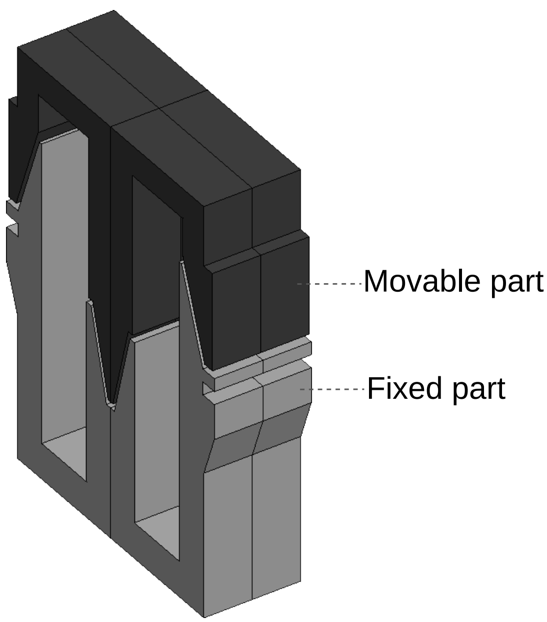
The project is saved under the name **GEO_MESH_PHYS.FLU**.

2.1 Geometry description process



Introduction

This section explains the geometry construction of the trident in the Modeler context of Flux 3D. The device is presented in the figure below.



Contents

This section explains the geometry construction of the trident in the Modeler context of Flux 3D.

- Create the fixed part
- Create the mobile part
- Add symmetries to the domain
- Add an infinite box to the domain

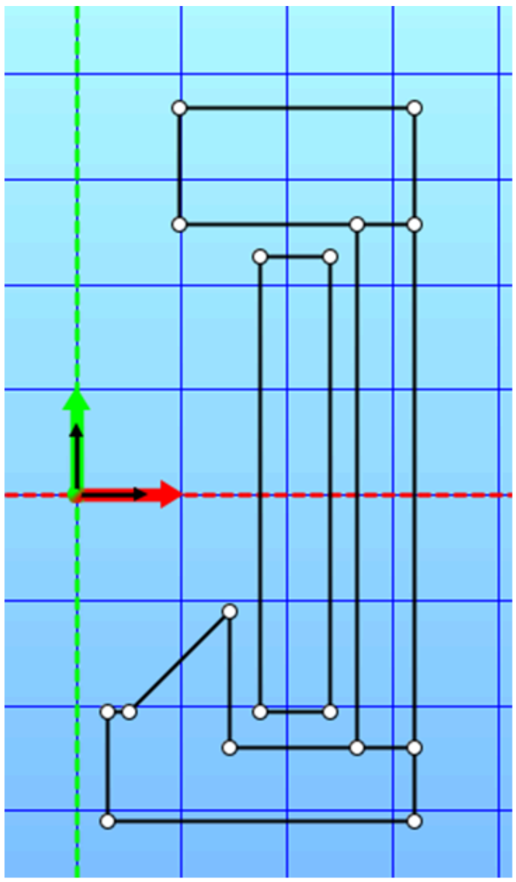
2.1.1 Create the fixed part

Goal

The fixed part (coil + magnetic circuit) is created in the Modeler context. The steps are presented in the following table.

Only 1/4 of the device will be modelled, as symmetry with physical properties will be created later in this document.

The outline of the fixed part is shown in the figure below.

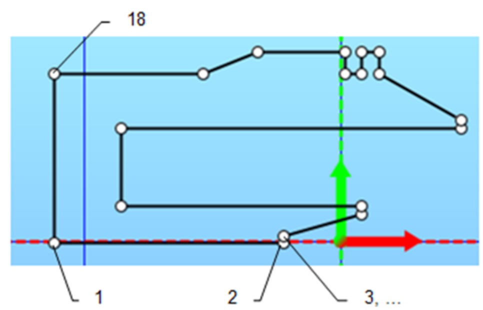
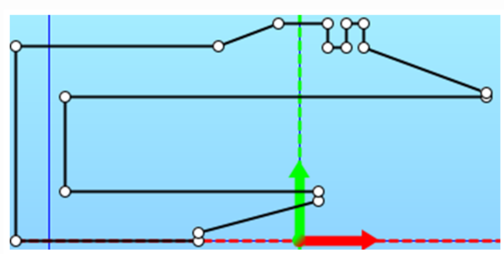


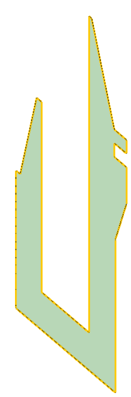
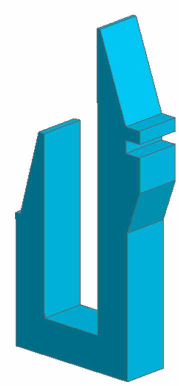
Action (1)

The steps of the construction of the magnetic circuit are presented in the following table.

Step	Action	Illustration
1	Create a sketch of the magnetic circuit on XZ plane by menu: **Tools** > **Sketch** > **New** (*access by icon:* )	

<table>
<tr><th>Step</th><th>Action</th><th>Illustration</th></tr>
<tr><td>2</td><td colspan="2">Modify the options of the grid:
<table>
<tr><th colspan="4">Option of the grid</th></tr>
<tr><th>Magnetization</th><th>Length of grid cell</th><th>Number of subdiv.</th><th>Number of points/subdiv</th></tr>
<tr><td>Yes</td><td>30</td><td>30</td><td>30</td></tr>
</table>

by menu: Option > Edit
(access by icon:)</td></tr>
<tr><td>3</td><td>Create the sketch using Polyline command, starting point 1 and ending point 18 as in the figure.
by menu: Construction > Line > Polyline
(access by icon:)</td><td>
</td></tr>
<tr><td>4</td><td>Modify the coordinates of all points:
<table>
<tr><th>Flux point</th><th>1st coord.</th><th>2nd coord.</th></tr>
<tr><td>1</td><td>-34</td><td>0</td></tr>
<tr><td>2</td><td>-12.15</td><td>0</td></tr>
<tr><td>3</td><td>-12.15</td><td>0.98</td></tr>
<tr><td>4</td><td>2.2</td><td>4.825</td></tr>
<tr><td>5</td><td>2.2</td><td>5.95</td></tr>
<tr><td>6</td><td>-28</td><td>5.95</td></tr>
<tr><td>7</td><td>-28</td><td>17.1</td></tr>
<tr><td>8</td><td>22.25</td><td>17.1</td></tr>
<tr><td>9</td><td>22.25</td><td>17.686</td></tr>
<tr><td>10</td><td>7.65</td><td>23</td></tr>
</table></td><td></td></tr>
</table>

<table>
<tr><th>Step</th><th>Action</th><th>Illustration</th></tr>
<tr><td></td><td>
<table>
<tr><th>Flux point</th><th>1st coord.</th><th>2nd coord.</th></tr>
<tr><td>11</td><td>7.65</td><td>25.85</td></tr>
<tr><td>12</td><td>5.475</td><td>25.85</td></tr>
<tr><td>13</td><td>5.475</td><td>23</td></tr>
<tr><td>14</td><td>3.3</td><td>23</td></tr>
<tr><td>15</td><td>3.3</td><td>25.85</td></tr>
<tr><td>16</td><td>-2.557</td><td>25.85</td></tr>
<tr><td>17</td><td>-9.7</td><td>23.25</td></tr>
<tr><td>18</td><td>-34</td><td>23.25</td></tr>
</table>
Select all points and choose: Edit array
(access by icon:)
</td><td></td></tr>
<tr><td>5</td><td>
Close the sketch context. The model appears as in the figure in the Flux Modeler
by menu: Project > Close Sketch context
(access by icon:)
</td><td></td></tr>
<tr><td>6</td><td>
Extrude the SKETCH_1 with the following characteristics:
<table>
<tr><th>Definition</th><th>Faces to extrude</th></tr>
<tr><td>EXTRUDE_1</td><td>face 1</td></tr>
</table>
</td><td></td></tr>
</table>

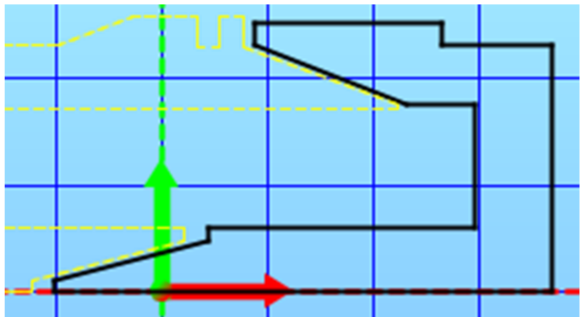
<table>
<tr><th>Step</th><th>Action</th><th>Illustration</th></tr>
<tr><td></td><td>
<table>
<tr><th colspan="5">Extrusion</th></tr>
<tr><th>Type</th><th>Coord. system</th><th>Formula or value</th><th>Length</th><th>Offset origin plane</th></tr>
<tr><td>Along a vector</td><td>COORDSYS_XZ_PLANE</td><td>0, 0, 1</td><td>8.05</td><td>0</td></tr>
</table>
by menu: Tools > Extrusion > New
(access by icon:)
</td><td></td></tr>
</table>

2.1.2 Create the mobile part

Goal

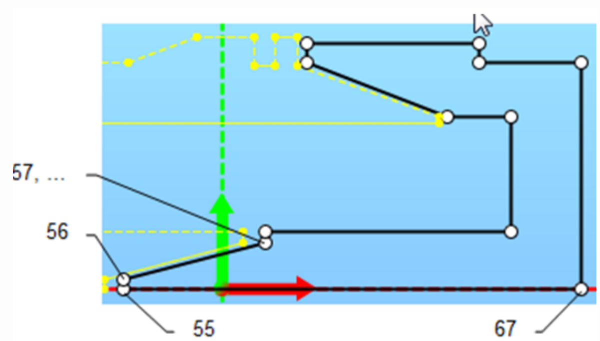
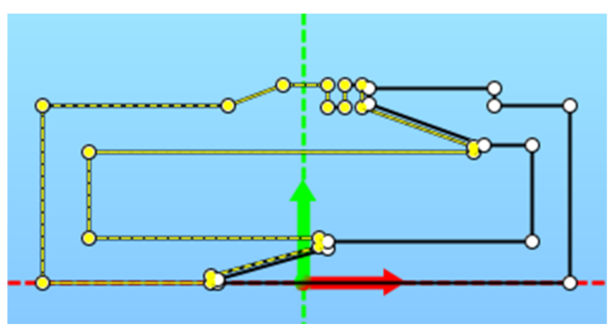
The mobile part is created in the Modeler context. The steps are presented in the following table.

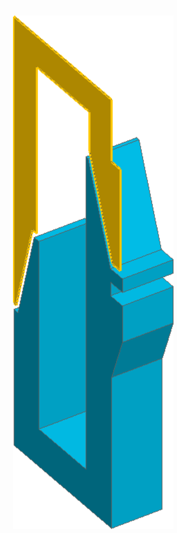
The outline of the mobile part is shown in the figure below.

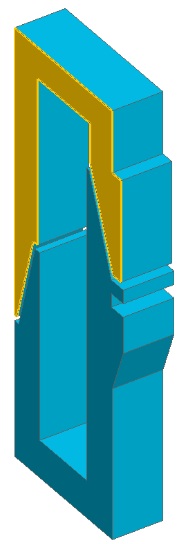


Action (1)

The steps of the construction of the magnetic circuit mobile part are presented in the following table.

<table>
<tr><th>Step</th><th>Action</th><th>Illustration</th></tr>
<tr><td>1</td><td colspan="2">Open the sketch created previously : SKETCH_1
by menu: Tools > Sketch > Open sketch > New
(access by icon:)</td></tr>
<tr><td>2</td><td>Create the sketch using Polyline command, starting point 55 and ending point 67 as in the figure.
by menu: Construction > Line > Polyline
(access by icon:)</td><td>
</td></tr>
<tr><td>3</td><td>Create a reference line by linking the two reference points. This reference line will be used to create the second reference plane around an angle.
<table>
<tr><th>Flux point</th><th>1st coord.</th><th>2nd coord.</th></tr>
<tr><td>55</td><td>-11.15</td><td>0</td></tr>
</table></td><td></td></tr>
</table>

<table>
<tr><th>Step</th><th>Action</th><th>Illustration</th></tr>
<tr><td></td><td>
<table>
<tr><th>Flux point</th><th>1st coord.</th><th>2nd coord.</th></tr>
<tr><td>56</td><td>-11.15</td><td>0.595</td></tr>
<tr><td>57</td><td>3.2</td><td>4.44</td></tr>
<tr><td>58</td><td>3.2</td><td>5.5</td></tr>
<tr><td>59</td><td>30</td><td>5.5</td></tr>
<tr><td>60</td><td>30</td><td>18</td></tr>
<tr><td>61</td><td>23.625</td><td>18</td></tr>
<tr><td>62</td><td>8.65</td><td>23.45</td></tr>
<tr><td>63</td><td>8.65</td><td>25.35</td></tr>
<tr><td>64</td><td>25</td><td>25.35</td></tr>
<tr><td>65</td><td>25</td><td>23.2</td></tr>
<tr><td>66</td><td>35</td><td>23.2</td></tr>
<tr><td>67</td><td>35</td><td>0</td></tr>
</table>
Select all points and choose: **Edit array**
(*access by icon:*)
</td><td></td></tr>
<tr><td>4</td><td>Close the sketch context. The model appears as in the figure in the Flux Modeler
by menu: **Projet** > **Close Sketch context**
(*access by icon:*)</td><td></td></tr>
</table>

<table>
<tr><th>Step</th><th>Action</th><th>Illustration</th></tr>
<tr><td>5</td><td>
Extrude the SKETCH_1 with the following characteristics:
<table>
<tr><th>Definition</th><th>System coord.</th><th>Faces to extrude</th></tr>
<tr><td>EXTRUDE_2</td><td>XYZ1</td><td>face 22</td></tr>
</table>
<table>
<tr><th colspan="5">Extrusion</th></tr>
<tr><th>Type</th><th>Coord. system</th><th>Formula or value</th><th>Length</th><th>Offset origin plane</th></tr>
<tr><td>Along a vector</td><td>COORDSYS_XZ_PLANE</td><td>0, 0, 1</td><td>8.05</td><td>0</td></tr>
</table>
by menu: Tools > Extrusion
(access by icon:)
Select Project > Return to standard geometry
(access by icon:)
</td><td></td></tr>
</table>

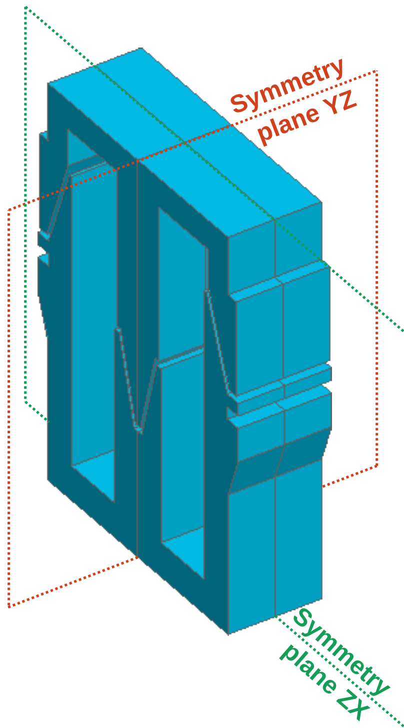
2.1.3 Add symmetries to the domain

Goal

Two symmetry planes – one parallel to the XZ plane and one parallel to the YZ plane – are created to model a quarter of the trident geometry.

Outline

The symmetry plane used in this study is shown in the figure below.



Data

The characteristics of the symmetries are presented in the tables below.

Symmetry versus YZ plane			
Name (automatic)	**Geometrical aspects**		**Physical aspects***
	Type	**Y offset position**	
COORDSYS_YZ_PLANE	Versus YZ plane	0	-

Symmetry versus ZX plane			
Name (automatic)	**Geometrical aspects**		**Physical aspects***
	Type	**Y offset position**	
COORDSYS_ZX_PLANE	Versus ZX-plane	0	-

Note: Physical aspects of the symmetries are specified in the section concerning the physical description.

Access

- by menu: **Geometry** > **Symmetry** > **New**
- by icon: 

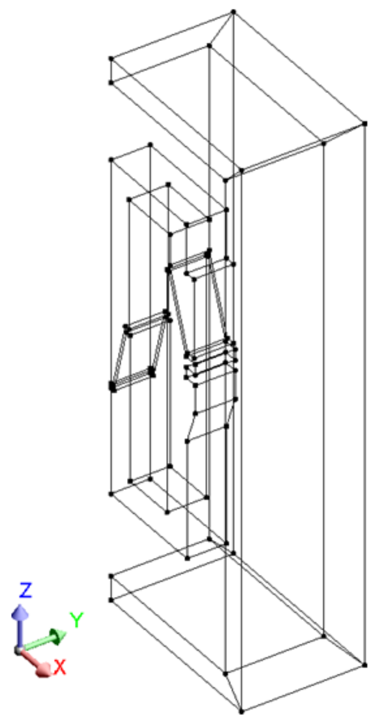
2.1.4 Add an infinite box to the domain

Goal

In order to automatically impose the natural condition of a zero magnetic field at infinity, the studied device is placed inside an infinite box. One quarter of the infinite box is modeled because of the presence of symmetries.

Data

The infinite box and its characteristics are presented below.



Infinite box of Parallelepiped type						
Name (automatic)	**X inner size, ½ length**	**X outer size, ½ length**	**Y inner size, ½ length**	**Y outer size, ½ length**	**Z inner size, ½ length**	**Z outer size, ½ length**
InfiniteBoxCube	35	40	20	25	51	56

Access

- by menu: **Geometry** > **Infinite box** > **New**
- by icon :

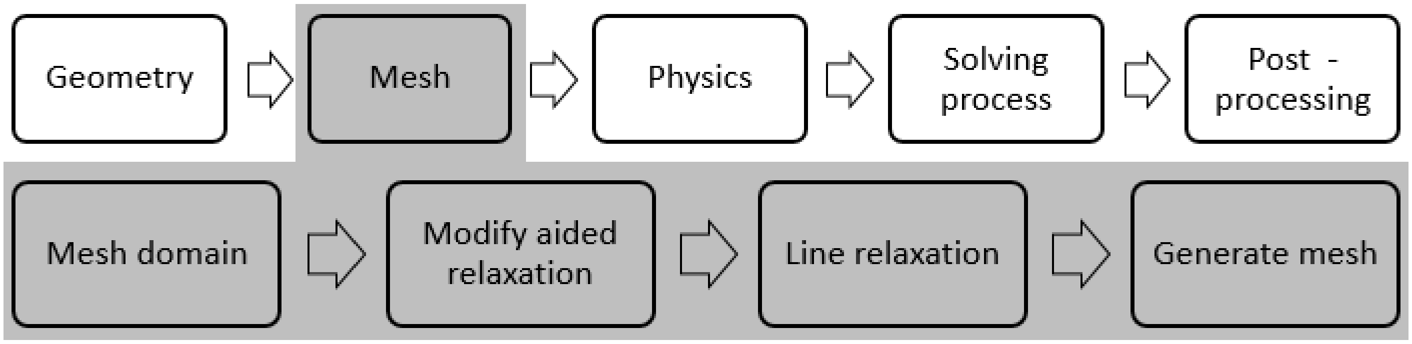
Action

Complete the Infinite box in order to close domain.

Access

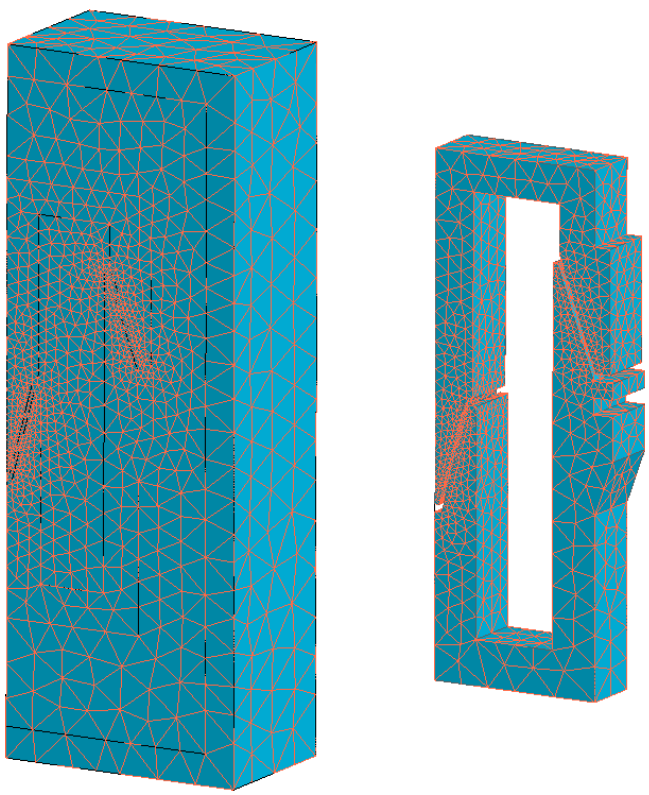
- by menu: **Geometry** > **Infinite box** > **Complete Infinite box**
- by icon: 

2.2 Mesh generation process



Introduction

This section presents the general steps of mesh generation for the computational domain and the data required to describe the trident mesh. The meshed device is presented in the figure below.



Contents

This section covers the following:

- Mesh the device
- Modify the aided relaxation
- Create and assign line relaxation
- Generate the mesh

2.2.1 Mesh the device

Goal

Mesh generation process is an essential step of the Finite Element method. At this stage, the computational domain is divided in small elements.

Each node of the mesh constitute a support where the **state variable** approximation (such as scalar or vector potentials, temperature, etc.) and the **derived fields** (such as magnetic field and induction, magnetic flux density, electric field, thermal flux density, etc.) are computed.

Aided mesh is activated by default in Flux. Such tool permits to obtain a first basic mesh with global settings.

.

Action

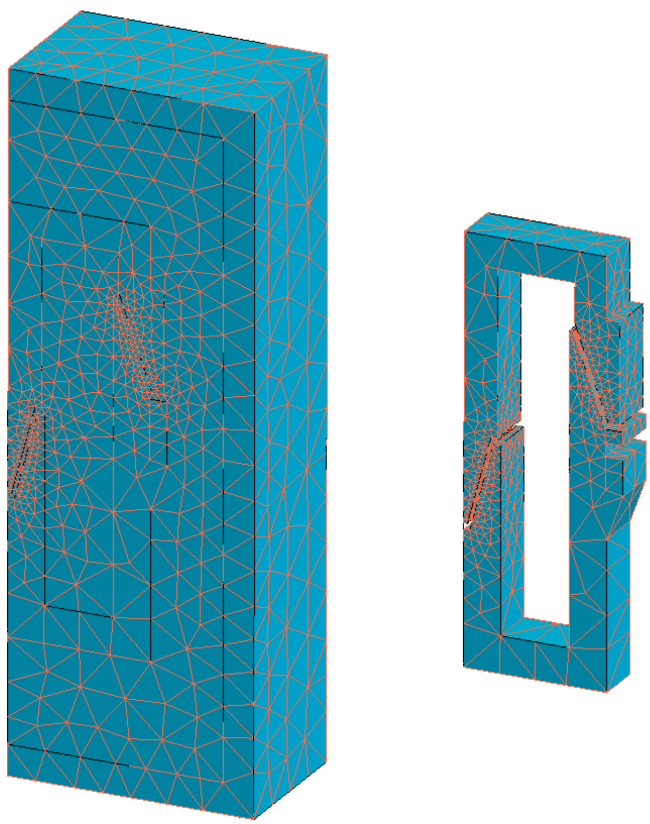
Mesh the device.

Access

- by menu: **Mesh** > **Mesh domain**
- by icon:

Result

The result appears as below.



Comments

To optimize the accuracy of the results, it is advised to have a mesh:

- with well proportioned mesh elements (close to equilateral triangle)
- taking into account the physics (the mesh must be denser in the areas with important field variation)

For instance, solutions to improve the mesh here are :

- to modify the aided relaxation
- to create and assign line relaxation

2.2.2 Modify the aided relaxation

Goal

The aided relaxation is modified in order to refine the global mesh, especially in the magnetic circuit..

Data

The modified characteristic of the aided mesh is presented in the table below.

Relaxation	
Aided Relaxline/Relaxface/Relaxvolume	**Setting of relaxation**
Assign	Low (r=0.25)

Access:

- by menu: **Mesh** > **Aided mesh** > **Edit**
- by icon: 

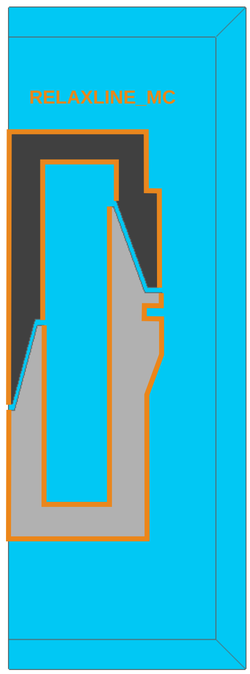
2.2.3 Create and assign line relaxation

Goal

One local line relaxation is created and assigned to control the density in an automatic mesh.

In order to refine the magnetic circuit mesh, **RELAXLINE_MC** line relaxation is created and assigned to the circuit lines except in the air gap.

The concerned lines are presented in the figure below.



Data

The characteristics of the line relaxation are presented in the table below.

Relaxation line				
Name	**Comment**	**Mesh relaxation on line**	**Coef.**	**Color**
RELAXLINE_MC	Trident lines	User	0.1	Green

Access

- by menu: **Mesh** > **Relaxation** > **Relaxation line** > **New**
- by icon: 

Action

Assign relaxation line to lines.

Access

- by menu: **Mesh** > **Assign mesh information** > **Assign relaxation / shadow** > **Assign relaxation to lines**
- by icon:

2.2.4 Generate the mesh

Goal

Lines, faces and volumes of the computation domain are meshed using the algorithm of automatic mesh generator to generate the first order elements. Then the second order elements are generated.

Action (1)

Mesh domain.

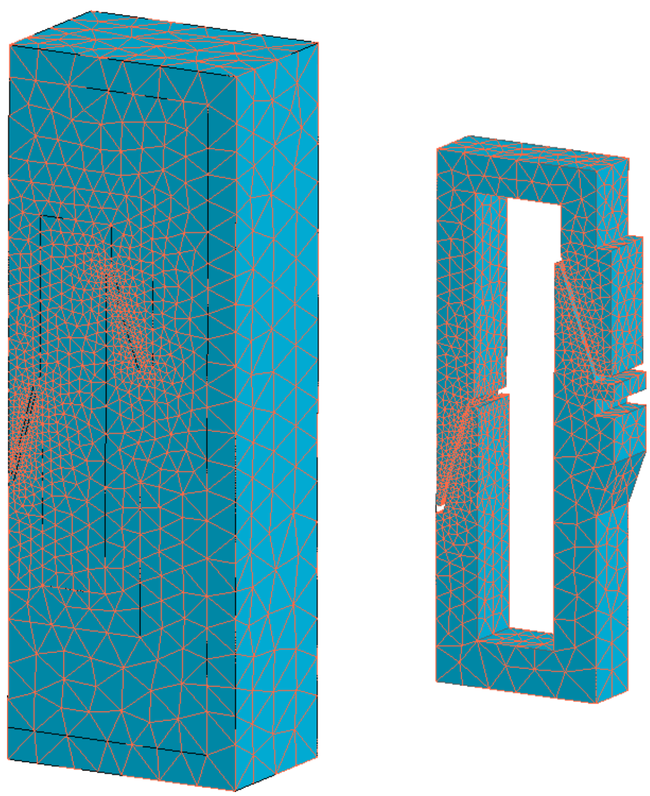
Access (1)

- by menu: **Mesh** > **Mesh domain**
- by icon:

> **Note:** Another solution is to select both commands **Mesh Faces** / **Mesh Volumes**.

Result

The resulting mesh of the computation domain is shown in the figure below.



Action (2)

Generate second order mesh elements

Access (2)

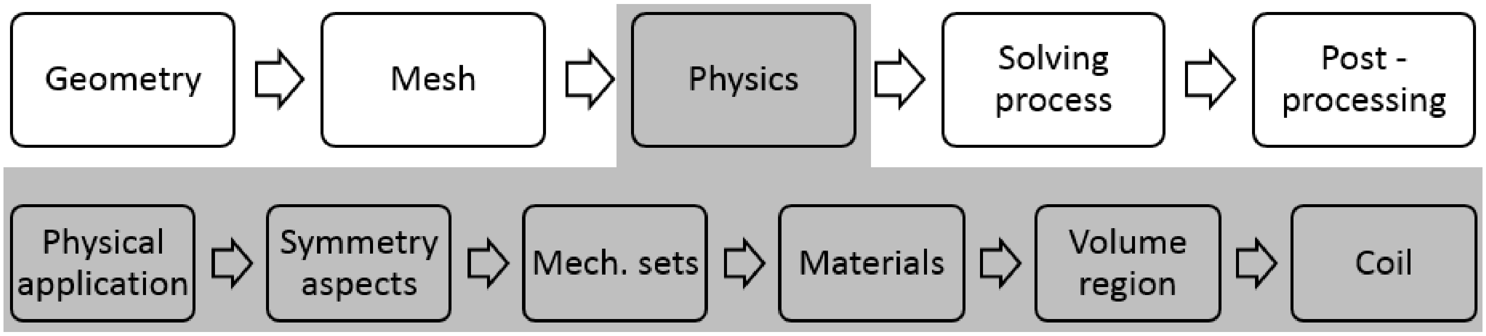
- by menu: **Mesh** > **Generate second order elements**
- by icon:

Result

Details of the resulting mesh of the trident are presented below.

```
Nombre d'elements non evalues : 0 %

Nombre d'elements d'excellente qualite : 46.12 %

Nombre d'elements de bonne qualite : 42.78 %

Nombre d'elements de qualite moyenne : 10.28 %

Nombre d'elements de qualite mediocre : 0.82 %
```

2.3 Physical description process



Introduction

This section presents the definition of the physical application, physical properties (materials, regions, coils) and kinematic properties (mechanical sets).

Contents

This section covers the following:

- Define the physical application
- Define physical aspects of symmetry
- Create mechanical sets
- Create materials
- Create and assign volume regions
- Create a coordinate system for a coil
- Create a source (electric components and coil)

2.3.1 Define the physical application

Goal

First, the physical application is defined. The required physical application is the 3D Magneto Static application.

Data

The characteristics of the application are presented in the table below.

<table>
<tr><th colspan="4">Magneto Static 3D application</th></tr>
<tr><th colspan="3">Formulation model</th><th rowspan="3">Coils coefficient</th></tr>
<tr><th rowspan="2">Formulation model</th><th>Order or finite element functions</th><th>Order of finite element functions</th></tr>
<tr><th>Scalar potential</th><th>Vector potential</th></tr>
<tr><td>Automatic formulations</td><td>Automatic</td><td>Automatic</td><td>Automatic coefficient</td></tr>
</table>

Access

by menu: **Application** > **Define** > **Magnetic** > **Magneto Static 3D**

2.3.2 Define physical aspects of symmetry

Goal

Physical aspects of the symmetries created in the geometry description are defined.

Data

The characteristics of the modified symmetries are presented in the table below.

Symmetry versus YZ plane		
Name (automatic)	**Geometrical aspects**	**Physical aspects**
SymmetryYZplane_1	Add symmetries to the domain	Tangent magnetic field, normal electric field, adiabatic condition

Symmetry versus ZX plane		
Name (automatic)	**Geometrical aspects**	**Physical aspects**
SymmetryZXplane_1	Add symmetries to the domain	Tangent magnetic field, normal electric field, adiabatic condition

2.3.3 Create mechanical sets

Goal

Three mechanical sets are created to define kinematic properties of the trident.

Data

The characteristics of the mechanical sets are presented in the table below.

Fixed Mechanical Set	
Name	**Comment**
FIXED_PART	Fixed part

Compressiblemechanical set		
Name	**Comment**	**Used method**
COMPRESSIBLE_PART	Compressible part surrounding the movable part	Re-meshing of the air part surrounding the moving body

Translation along one axis mechanical set				
Name	**Comment**	**Axis**		**Kinematcs**
		Translation axis	**Coord. system**	
TRANSLATION _PART	Movable part	along Z	XYZ1	Multi-static

Access

by menu: **Physics** > **Mechanical set** > **New**

- by menu: **Physics** > **Mechanical set** > **New**
- by icon: 

2.3.4 Create materials

Goal

One material characterized by a nonlinear **B(H)** curve is created directly for the physical description of the trident.

Data

The characteristics of the material are presented in the table below.

B(H) magnetic property: isotropic analytic saturation + knee adjustment				
Name	**Comment**	**Initial relative permeability**	**Saturation magnetization [T]**	**Knee adjustment coeff.**
FESI	Nonlinear magnetic steel	2500	2.01	0.075

Access

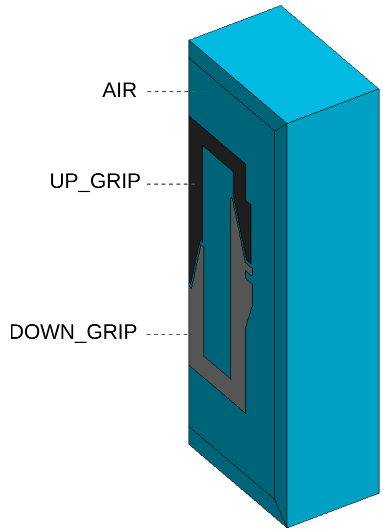
- by menu: **Physics** > **Material** > **New**
- by icon: 

2.3.5 Create and assign volume regions

Goal

Three volume regions necessary for the physical description of the trident are created and assigned to volumes.

The volumes volume regions are shown in the figure below.



Data

The characteristics of the volume regions are presented in the table below.

Volume region					
Name	**Comment**	**Type**	**Material**	**Color**	**Mech. set**
AIR	Air surrounding the upper and lower grips	Air or vacuum region	-	Turquoise	COMPRESSIBLE _PART
UP_GRIP	Upper trident grip	Magnetic non-conducting region	FESI	Grey_anthracite	TRANSLATION _PART
DOWN_GRIP	Lower trident grip	Magnetic non-conducting region	FESI	Grey_steel	FIXED_PART

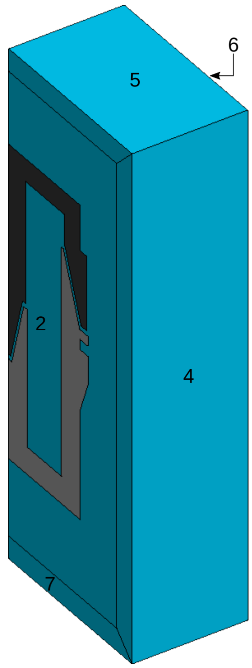
Access

- by menu: **Physics** > **Volume region** > **New**
- by icon: 

Action (1)

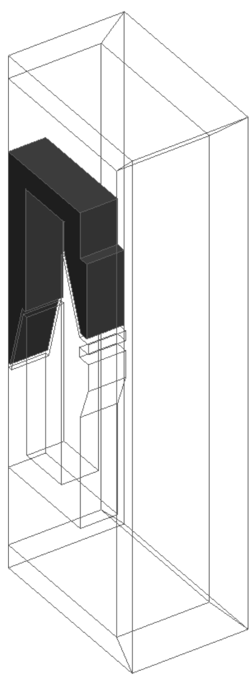
The AIR volume region is assigned to the five volumes of infinite box.

The five volumes of the AIR region are presented in the figure below.



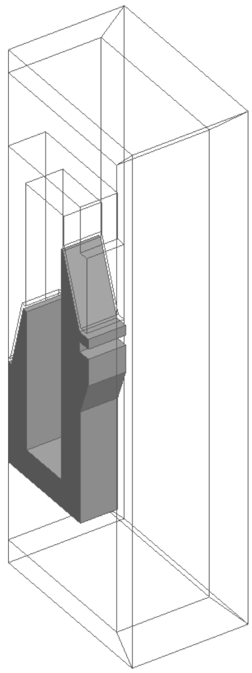
Action (2)

The UP_GRIP volume region is assigned to the volume of the movable part.



Action (3)

The DOWN_GRIP volume region is assigned to the volume of the fixed part.



Access

- by menu: **Physics** > **Assign regions to geometric entities** > **Assign regions to volumes (completion mode)**
- by icon: 

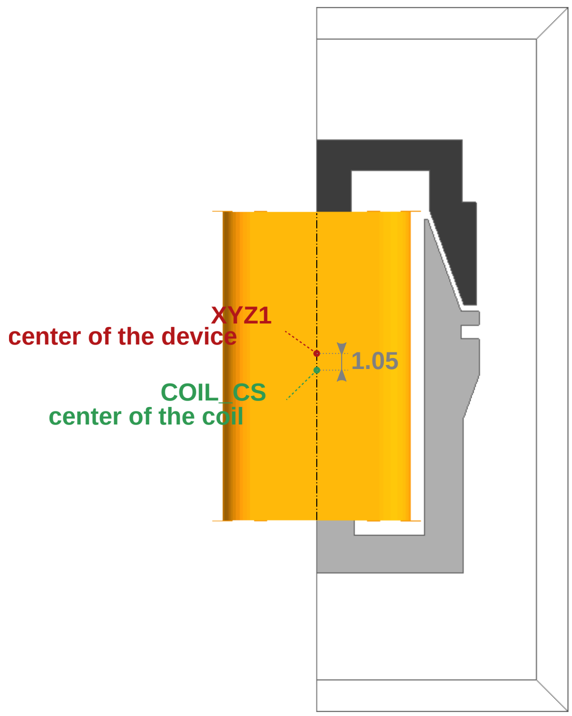
2.3.6 Create a coordinate system for a coil

Goal

One coordinate system is created to define a non-meshed coil.

Data

The coordinate system and its characteristics are presented below



Cartesian coordinate systemdefined with respect to the Local coordinate system								
Name	Comment	Parent coord. system	Origin coordinates			Rotation angle		
			1st (X)	2d (Y)	3rd (Z)	About X-axis	About Y-axis	About Z-axis
COIL_CS	For a coil	XYZ1	0	0	-1.05	0	0	0

Access

- by menu: **Geometry** > **Coordinate system** > **New**
- by icon: 

2.3.7 Create a source (electric components and coil)

Goal

One non-meshed coil with an associated electric component (of coil conductor type) is created to model a current source of the trident.

Data (1)

The characteristics of the electric component (of coil conductor type) are presented in the table below.

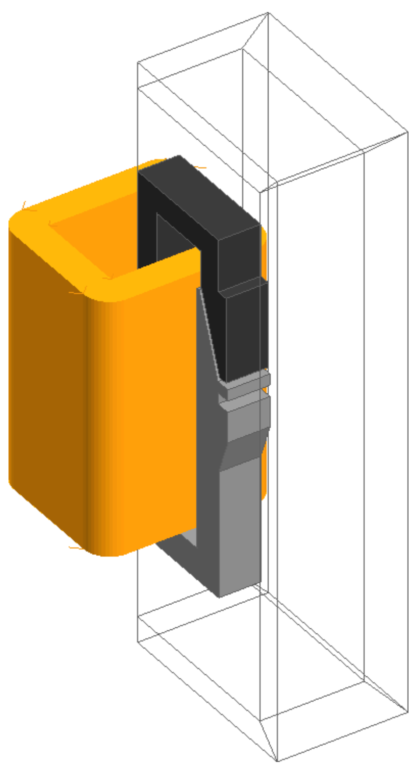
Stranded coil with imposed current (A)			
Name	**Comment**	**Value**	**Color**
SOURCE	Current source of coil	0.3	Orange

Access (1)

- by menu: **Physics** > **Electrical components** > **Stranded coil conductor** > **New**
- by icon:

Data (2)

The non-meshed coil and their characteristics are presented below.



Rectangular coil: geometric definition						
Coil				Dimension		Filet radius
Number	Coord. system	Center	Radius	Along X	Along Y	Thickness
1	COIL_CS	0, 0, 0	9	24	28	2

Rectangular coil: geometric definition			
Coil section			Mechanical set
Type	Height	Width	
Rectangle	49.2	6	FIXED_PART

Rectangular coil: electrical definition			
Electric component associated with the coil	Number of turns	Conductors in series or in parallel	Symmetries and periodicities: duplication or none
SOURCE	3250	... in series	duplication

Access

- by menu: **Physics** > **Non meshed coil** > **New**
- by icon: 

Case 1: Study using the multi-static kinematic model (different linear positions) 3

This chapter covers the following:

Case 1

The first case is a study using the multi-static kinematic model (Magneto Static application):

In this case (multi-static kinematic model), the moving part of the device can take various positions fixed arbitrarily.

We are interested in the computation of the magnetic field for **arbitrarily chosen positions** of the mobile grip.

With this model it is possible to evaluate the force acting on the fixed grip at different positions.

Starting Flux project

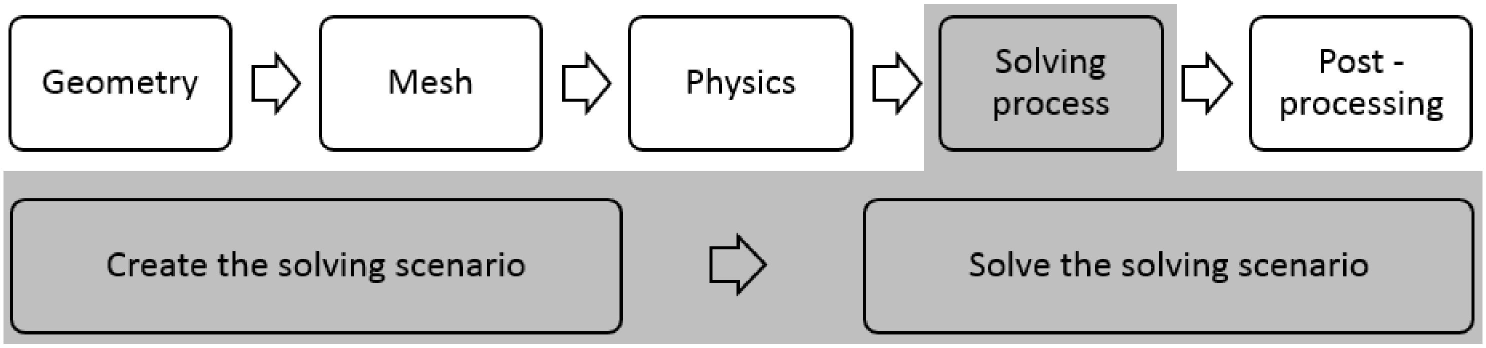
The starting Flux project is **GEO_MESH_PHYS.FLU**. This project contains:

- the geometry description of the contactor
- the mesh of the computation domain
- the initial physical description of the contactor

New Flux project

The new Flux project is **CASE1.FLU**.

3.1 Case 1: Solving process



Introduction

This section explains how to prepare and solve case 1.

Contents

This section contains the following topics:

3.1.1 Define solving scenario and solve the project

Goal

The solving scenario with one controlled parameter for mechanical set is defined for a solving process, and then case 1 is solved.

Data

The characteristics of the scenario for the solving process are presented in the table below.

Solving scenario		
Name	**Comment**	**Type**
CASE1	Multi-static kinematic model	Multi-values

Solving scenario				
Parameter control				
Controlled parameter	**Interval**			
	Lower endpoint	**Upper endpoint**	**Method**	**Step value**
LINPOS_ TRANSLATION_PART	0.006	0	Step value	-0.0005

Access

- by menu: **Solving** > **Solving scenario** > **New**
- by icon: 

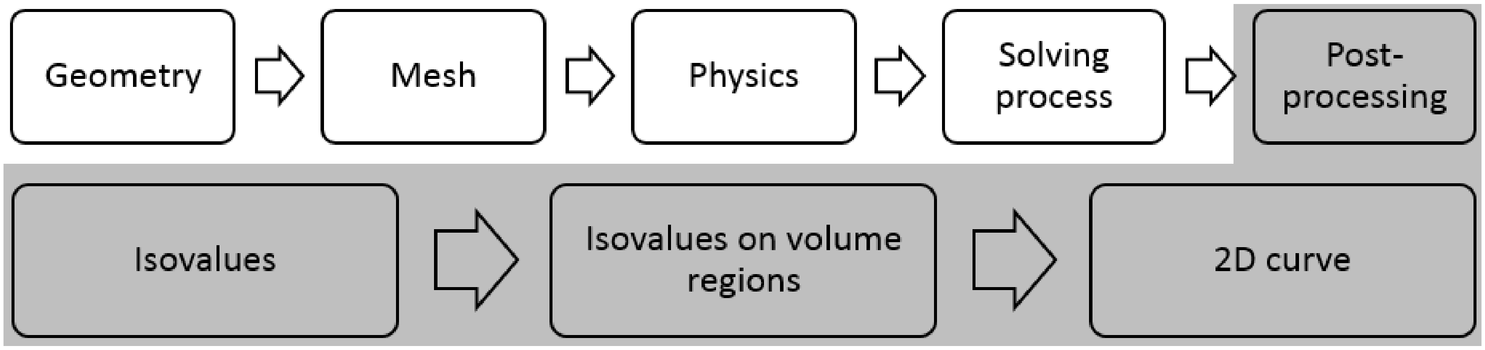
Action

The project is solved using the CASE1 scenario.

Access

- by menu: **Solving** > **Solve**
- by icon: 

3.2 Case 1: Results post-processing



Introduction

This section explains how to analyze the principal results of case 1.

Contents

This section contains the following topics

- Display default isovalues
- Compute and display isovalues of the relative permeability on volume regions
- Plot a 2D curve of the electromagnetic force versus the linear position

3.2.1 Display default isovalues

Goal

First, the computation step of the study using a multi-static kinematic model is selected; then, the scalar quantities of the magnetic flux density on the volume regions are computed and displayed via isovalues plots of color shadings.

Data

The characteristics* of the scenario and computation step selection are presented in the table below.

Scenario and computation step selection		
Scenario	**Computation step**	
	Parameter name	**Value**
CASE1	LINPOS_TRANSLATION_PART	0

Action

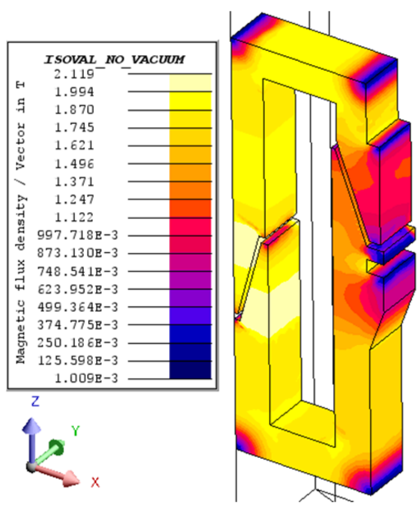
Display isovalues (**ISOVAL_NO_VACUUM**).

Access

- by menu: **Graphic** > **Isovalues** > **Display Isovalues**
- by icon:

Result

This chart shows the magnetic flux density on the **DOWN_GRIP** and **UP_GRIP** volume regions.



> **Note:** *These characteristics are located in the dialog box below the data tree.

3.2.2 Compute and display isovalues of the relative permeability on volume regions

Goal

The scalar quantities of the relative permeability is computed on the volume regions and displayed via isovalues plots of color shadings for the following computation step previously selected: **LINPOS_TRANSLATION_PART = 0**.

Data

The characteristics of isovalues are presented in the table below.

Isovalues on spatial groups	
Volume region	**Formula**
V_DOWN_GRIP ; V_UP_GRIP	Mur

Action

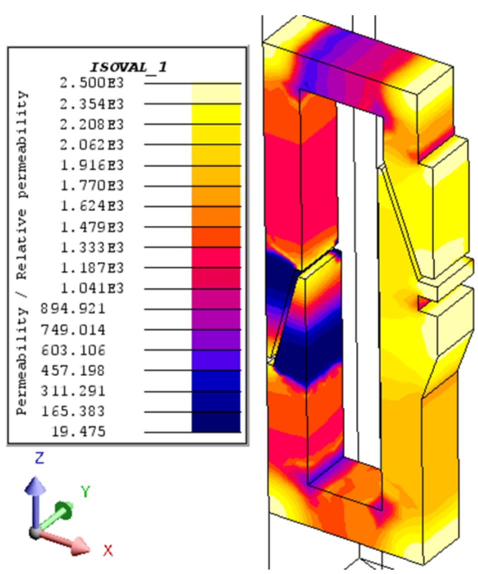
Create isovalues (**ISOVAL_1**).

Access

- by menu: **Graphic** > **Isovalues** > **New**
- by icon: 

Result

This chart shows the relative permeability on the **DOWN_GRIP** and **UP_GRIP** volume regions.



3.2.3 Plot a 2D curve of the electromagnetic force versus the linear position

Goal

The variation of the electromagnetic force versus the linear position is computed and displayed as curve.

Data

The characteristics of the curve are presented in the table below.

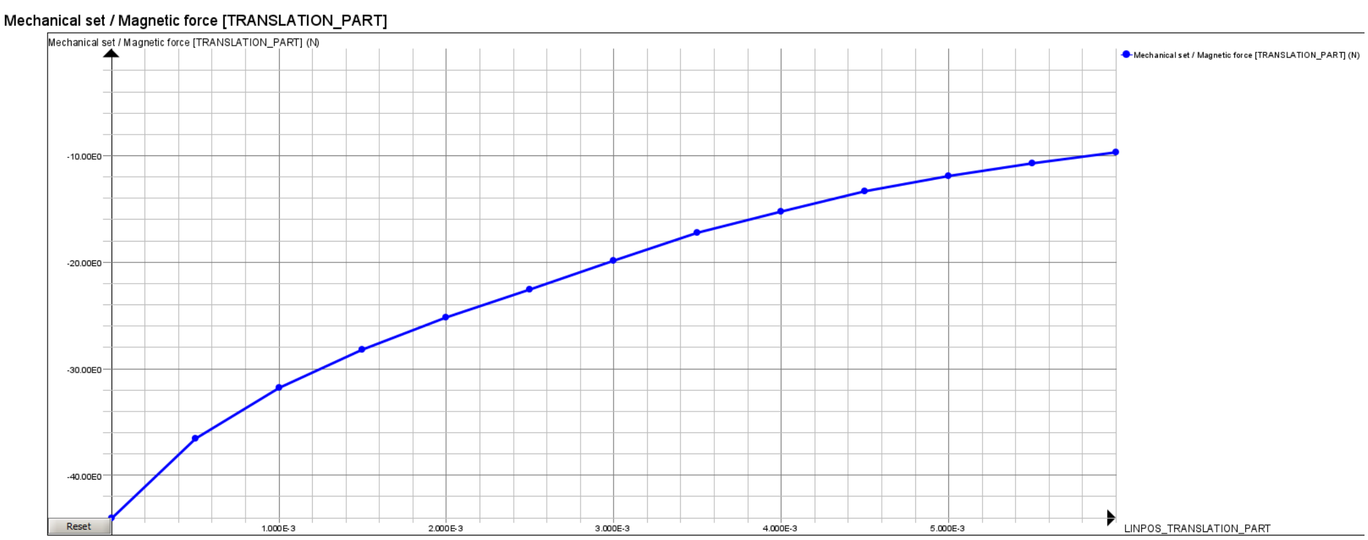
2D curve (I/O parameter)						
Name	**Comment**	**Parameter**			**Mechanical set**	
		Name	**Limit min.**	**Limit max.**	**Mec. set**	**Quantity**
CURVE	Force	LINPOS_ TRANSLATION_PART	0	0.006	TRANSLATION_PART	Electromagnetic force

Access (1)

- by menu: **Curve** > **2D curve (I/O parameter)** > **New 2D curve (I/O parameter)**
- by icon:

Result

The following curve shows the variation of electromagnetic force for different values of the linear position.



Case 2: Study using the coupled load kinematic model (with circuit coupling)

4

This chapter covers the following:

Case 2

The second case is a parametric study using the coupled load kinematic model (Transient Magnetic application)

In this case (coupled load kinematic model), a resistant force is exerted on the moving part of the device by means of a system of return springs; the coil is supplied by an external electric circuit (voltage source).

The advantage of this model is to study the time variation of :

- The position of the mobile grip
- The speed of the mobile grip
- The electromagnetic force acting on the mobile grip
- The current through the coil
- The flux through the coil

Starting Flux project

The starting Flux project is **GEO_MESH_PHYS.FLU**.

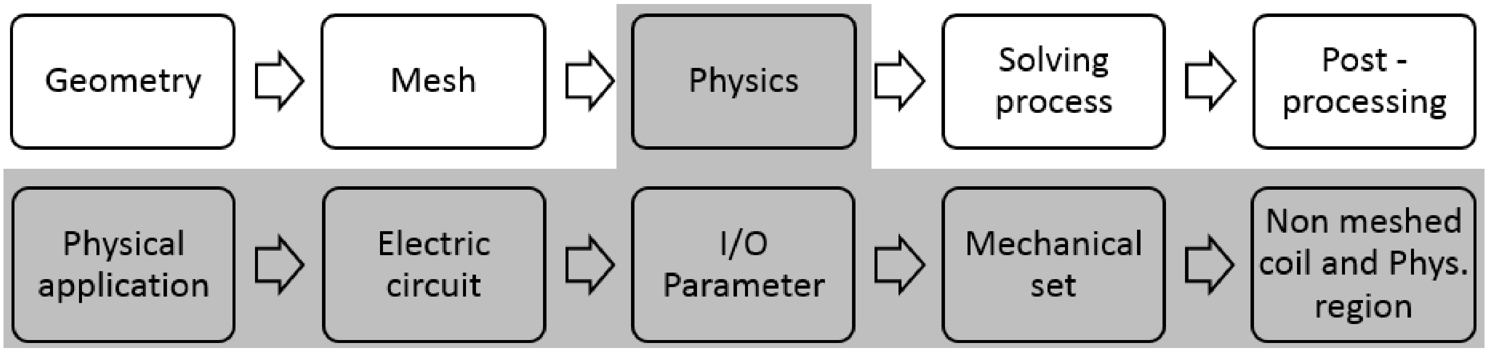
This project contains:

- the geometry description of the contactor
- the mesh of the computational domain
- the initial physical description of the contactor

New Flux project

The new Flux project is saved under the name **CASE2.FLU**.

4.1 Case 2: Physical description



Introduction

This section explains how to prepare and solve case 2.

Contents

- Define the physical application
- Import the electric circuit
- Define the circuit component
- Create an I/O parameter
- Modify a mecanical set
- Redefine the non meshed coil and the physical regions

4.1.1 Define the physical application

Goal

First, the current physical application is deleted, and then the new physical application is defined. The required physical application for case 2 is the 3D Transient Magnetic application.

Data

The characteristics of the application are presented in the table below.

3D Transient Magnetic application				
Formulation model				Coils coefficient
Formulation model	Approximating functions	Approximation order for scalar variable	Approximation order for vector variable	
Automatic formulations	Nodal finite elements	Automatic	Automatic	Automatic coefficient

Action (1)

Delete the current application.

Access (1)

by menu: **Application** > **Delete current application**

Action (2)

Define the 3D transient magnet application.

Access (2)

by menu: **Application** > **Define magnetic application** > **Transient magnetic application**

4.1.2 Import the electric circuit

Goal

An existing electric circuit is imported in the project.

Action

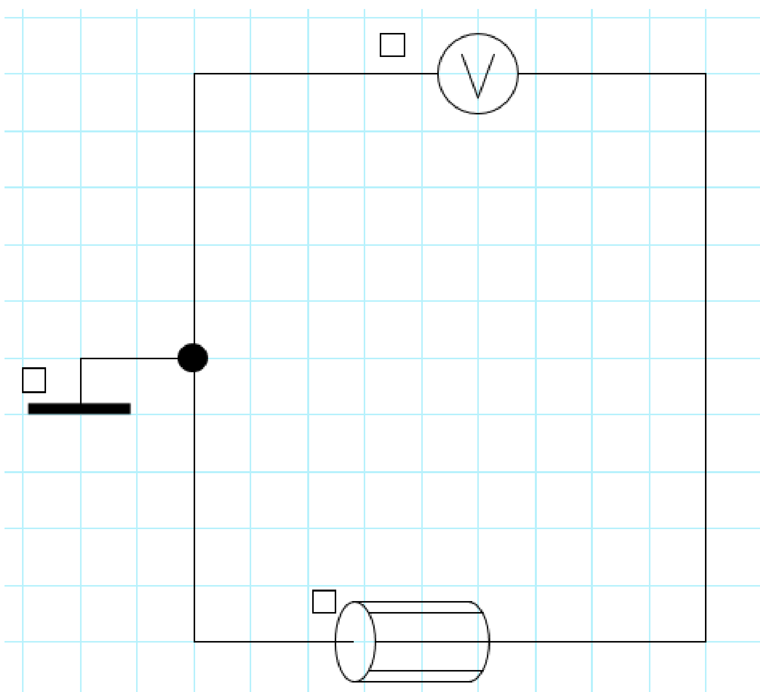
Import the electric circuit `CASE2.ccs` into the project `CASE2.FLU`.

Access

- by menu: **Physics** > **Circuit** > **Import circuit from a ccs file**
- by icon: 

Result

After importation, the electric circuit of the new project looks like the figure below.



4.1.3 Define the circuit component

Goal

The components of the imported electric circuit are defined.

Data (1)

The modified characteristics of the stranded coil of the imported electric circuit are presented in the table below.

Stranded coil belonging to a circuit		
Name	**Comment**	**Resistance formula [Ω]**
B1	-	73

Access (1)

- by menu: **Physics** > **Electrical component** > **Edit**

Data (2)

The modified characteristics of the voltage source of the imported electric circuit are presented in the table below.

Voltage source		
Name	**Comment**	**Value [V]**
V1	-	24

Access (2)

- by menu: **Physics** > **Voltage source** > **Edit**

4.1.4 Create an I/O parameter

Goal

An I/O parameter is created to describe the resistive force in the **TRANSLATION_PART** mechanical set.

Data

The characteristics of the parameter are presented in the tables below.

Parameter defined by a table of values		
Name	**Comment**	**I/O parameter for the abscissa**
RF	Resistive force	LINPOS_TRANSLATION_PART

Parameter defined by a table of values	
Abscissa	**Ordinate**
0	10.9
0.0014	9.4
0.002	4.7
0.0036	4.5
0.0037	2.8
0.006	2.7

Access

- by menu: **Parameter/Quality** > **I/O Parameter** > **New**
- by icon: 

4.1.5 Modify a mecanical set

Goal

The mechanical set **TRANSLATION_PART** is modified to describe the kinematic properties of the device using its resistant force.

Data (1)

The modified characteristics of the mechanical set are presented in the table below:

Translation along one axis mechanical set				
Name	**Comment**	**Axis**		**Kinematics**
		Translation axis	**Coord. system**	
TRANSLATION _PART	Movable part	along Z	UP	Coupled load

Translation along one axis mechanical set				
General		**Internal characteristics**		
Velocity	**Position**	**Type of load**	**Mass**	**Resistive force**
0	6E-3	Mass and resistive force	0.11	-RF

Translation along one axis mechanical set				
External characteristics			**Mechanical stops**	
Type of load	**Mass**	**Resistive force**	**Min**	**Max**
Mass and resistive force	0	0	-0.3863E-3	6E-3

Access

by menu: **Physics** > **Mechanical set** > **Edit**

4.1.6 Redefine the non meshed coil and the physical regions

Goal

The following physical information are changed:

- The non-meshed coil is modified to link the non-meshed coil to the electric component (of stranded coil type) of the imported electric circuit
- All the volume regions are modified to activate them in the Transient Magnetic application
- The unused coil conductor **SOURCE** is deleted

Data (1)

The modified characteristics of the non-meshed coil are presented in the table below.

Rectangular coil: electrical definition			
Electric comp. assoc. with the coil	**N° of turns**	**Conductors in series or in parallel**	**Symm. and periodicities: duplication or none**
B1	3250	… in series	duplication

Access (1)

by menu: **Physics** > **Non meshed coil** > **Edit**

Data (2)

The modified characteristics of the volume regions are presented in the table below.

Volume region					
Name	**Comment**	**Type**	**Material**	**Color**	**Mechanical set**
AIR	Air around upper and lower grips	Air or vacuum region	-	Turquoise	COMPRESSIBLE _PART
UP_GRIP	Upper trident grip	Magnetic non-conducting region	FESI	Grey_anthraci	TRANSLATION _PART
DOWN_GRIP	Lower trident grip	Magnetic non-conducting region	FESI	Grey_steel	FIXED_PART

Access (2)

by menu: **Physics** > **Volume region** > **Edit**

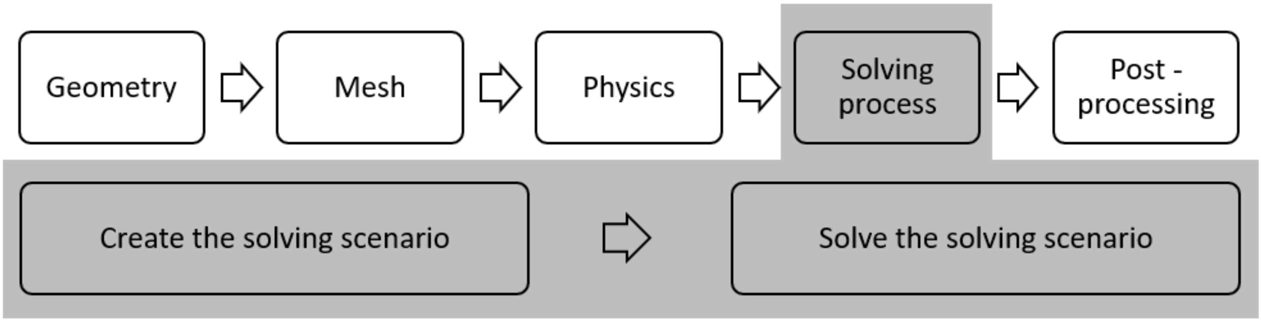
Action

The **SOURCE** coil conductor used in case 1 is deleted.

Access

by menu: **Physics** > **Electrical components** > **Stranded coil conductor** > **Delete**

4.2 Case 2: Solving process



Introduction

This section explains how to prepare and solve case 2.

Contents

This section contains the following topics:

4.2.1 Define solving scenario, solving options and solve the project

Goal

The scenario is defined for a transient solving process; the solving options are defined to improve the convergence of the New-Raphson solving process; then case 2 is solved.

Data (1)

The characteristics of the solving scenario are presented in the table below.

Solving scenario		
Name	**Comment**	**Control of transient state**
CASE2	Coupled load kinematic model	Control by time

Solving scenario - Parameter control				
Controlled parameter	**Interval**			
	Lower limit	**Higher limit**	**Method**	**Step value**
TIME	0	0.02	Step value	0.0025
	0.02	0.06		0.001
	0.06	0.15		0.0025

Access (1)

- by menu: **Solving** > **Solving scenario** > **New**
- by icon: 

Data (2)

The characteristics of the solving options are presented in the table below.

Advanced solving options			
Method for TO computation	**Reinitialization of state variables at the beginning of a time step**	**Project saving frequency**	
Automatically specified	No state variable set to 0	Saving one step to N	N=1

Access (2)

Step 2: Solve this scenario

- by menu: **Solving** > **Solving process options** > **Edit**
- by icon:

Action

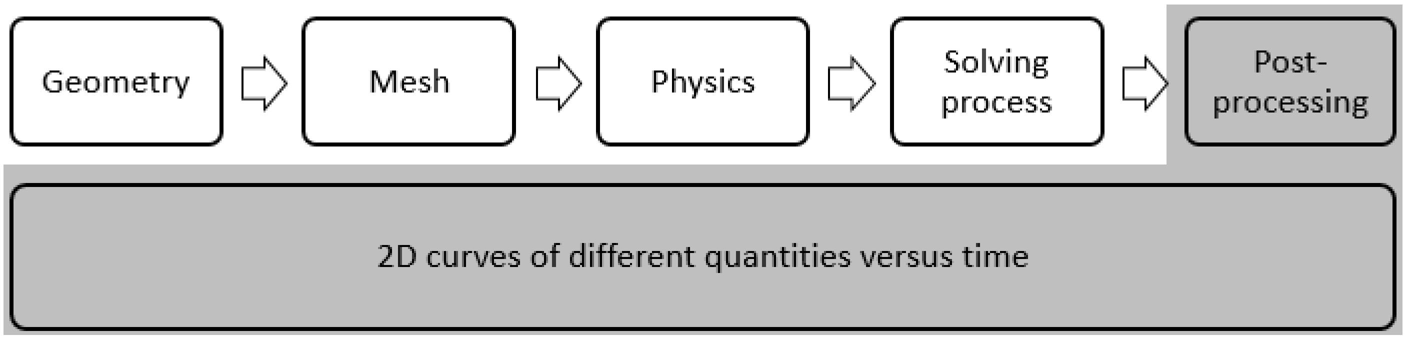
The project is solved using the CASE2 scenario.

Access

Step 2: Solve this scenario

- by menu: **Solving** > **Solved**
- by icon:

4.3 Case 2: Results post-processing



Introduction

This section explains how to analyze the principal results of case 2.

Contents

This section contains the following topics:

4.3.1 Plot a 2D curve of the linear position versus time

Goal

The values of the linear position versus time are computed and displayed as curve.

Data

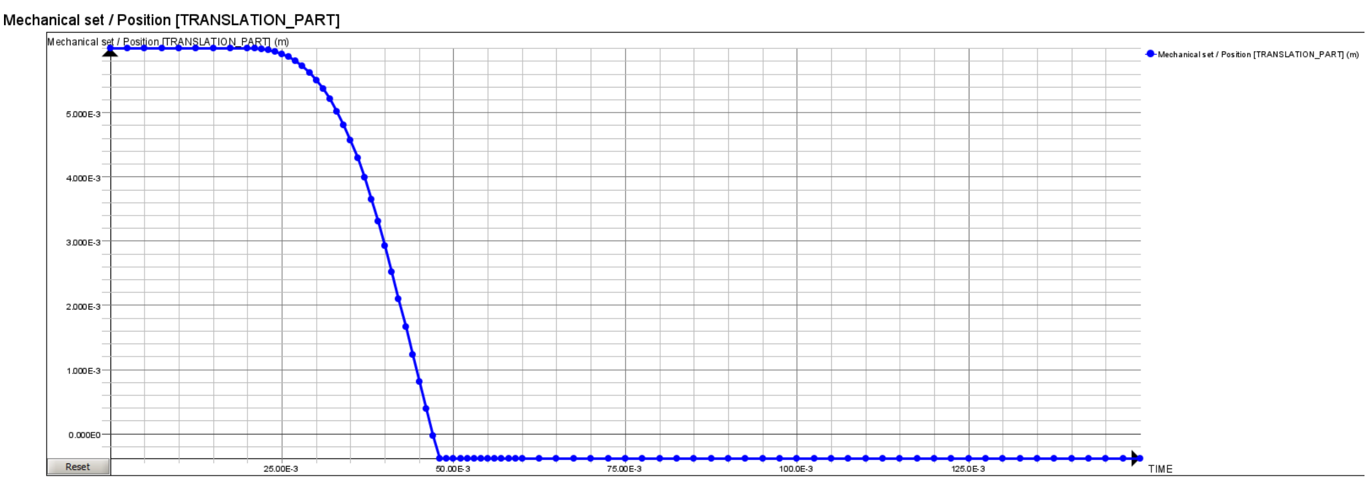
2D curve (I/O parameter)						
Name	**Comment**	**Parameter**			**Mechanical set**	
		Name	**Limit min**	**Limit max**	**Mech. set**	**Quantity**
POSITION	Linear position versus time	TIME	0.0	0.15	TRANSLATION _PART	Linear position

Access

- by menu: **Curve** > **2D Curve (I/O parameter)** > **New 2D Curve (I/O parameter)**
- by icon: 

Result

The following curve shows the variation of linear position for different values of time.



4.3.2 Plot a 2D curve of the translating part speed versus time

Goal

The values of the linear speed versus time are computed and displayed as curve.

Data

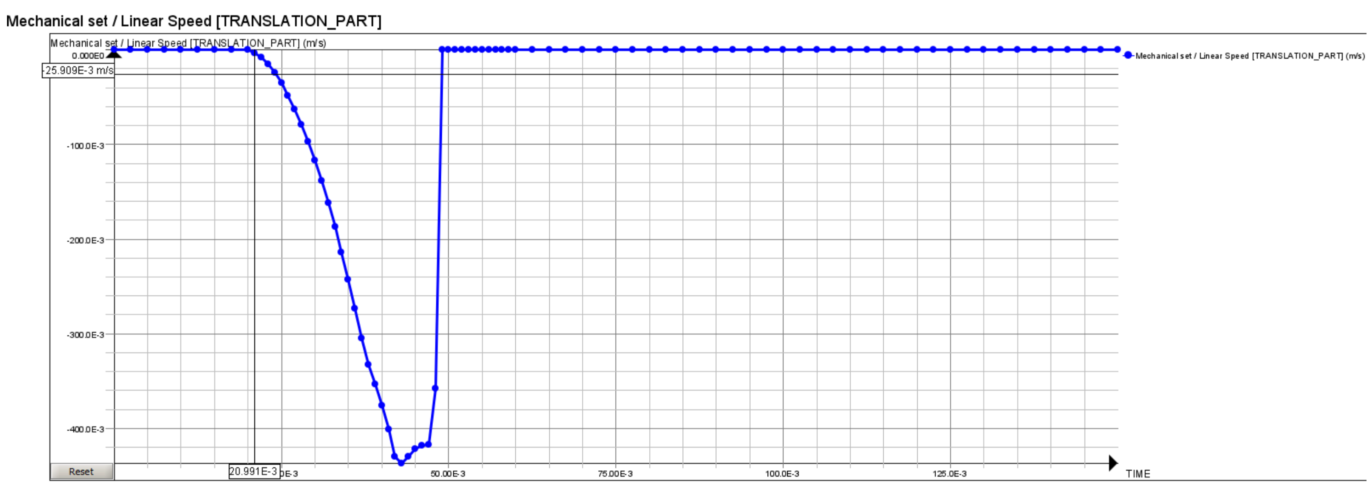
2D curve (I/O parameter)						
Name	**Comment**	**Parameter**			**Mechanical set**	
		Name	**Limit min**	**Limit max**	**Mech. set**	**Quantity**
SPEED	Linear speed versus time	TIME	0.0	0.15	TRANSLATION _PART	Linear speed

Access

- by menu: **Curve** > **2D Curve (I/O parameter)** > **New 2D Curve (I/O parameter)**
- by icon: 

Result

The following curve shows the variation of speed for different values of time.



4.3.3 Plot a 2D curve of the current through the coil versus time

Data

The values of the current through the coil versus time are computed and displayed as curve.

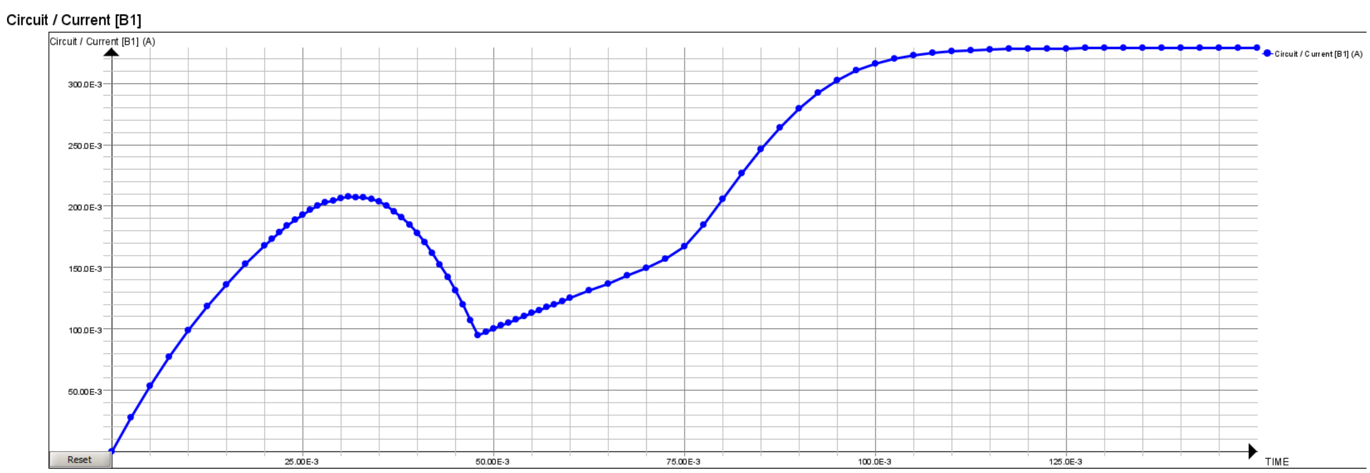
2D curve (I/O parameter)						
Name	Comment	Parameter			Circuit	
		Name	Limit min	Limit max	Stranded coil conductor	Quantity
CURRENT	Current through the coil versus time	TIME	0.0	0.15	B1	Current

Access

- by menu: **Curve** > **2D Curve (I/O parameter)** > **New 2D Curve (I/O parameter)**
- by icon:

Result

The following curve shows the variation of current through the coil for different values of time.



4.3.4 Plot a 2D curve of the flux through the coil versus time

Data

The values of the flux versus time are computed and displayed as curve.

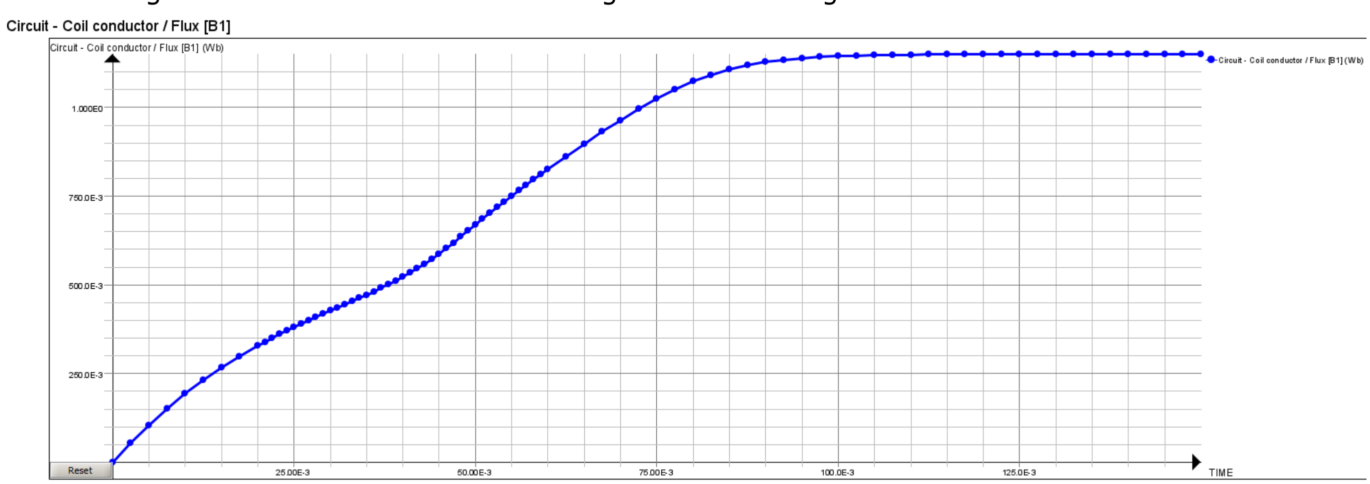
2D curve (I/O parameter)						
Name	**Comment**	**Parameter**			**Circuit**	
		Name	**Limit min**	**Limit max**	**Stranded coil conductor**	**Quantity**
FLUX	Magnetic flux through the coil versus time	TIME	0.0	0.15	B1	Flux

Access

- by menu: **Curve** > **2D Curve (I/O parameter)** > **New 2D Curve (I/O parameter)**
- by icon:

Result

The following curve shows the variation of magnetic flux through the coil for different values of time.



4.3.5 Plot a 2D curve of the electromagnetic force versus time

Data

The values of the electromagnetic force versus time are computed and displayed as curve.

2D curve (I/O parameter)						
Name	**Comment**	**Parameter**			**Mechanical set**	
		Name	**Limit min**	**Limit max**	**Mech set**	**Quantity**
FORCE	Electromagnetic force versus time	TIME	0.0	0.15	TRANSLATION_PART	Electromagnetic force

Access

- by menu: **Curve** > **2D Curve (I/O parameter)** > **New 2D Curve (I/O parameter)**
- by icon:

Result

The following curve shows the variation of electromagnetic force for different values of time.