2D Motion, 3D Motion, The "Motion Story" ...

Marc Vilcot - CEDRAT.

A large part of electromagnetic and electromechanical devices includes moving parts. In order to design these devices with a maximum of accuracy, CEDRAT, LEG and their industrial partners have developed numerical methods to take into account in the best way the motion and the associated effects (back emf, eddy currents, …).
Historically, this *"motion evolution"* started in 1990 and last results were proposed with the large 3D motion capabilities, with or without contact, of FLUX version 8.1. All features developed offered the capability to take into account multi-positions, constant speed or variable speed by kinematics coupling.

1990:

Eddy current effects in a massive rotor.

The results of the Ph.D. thesis of Mr. Eric VASSENT for the modelling of induction machines (collaborative work between *LEG*, *Moteurs Leroy Somer* and *EDF*) are implemented in FLUX. It enables to take into account the rotating motion in 2D models thanks to remeshing techniques of the air gap. All other parts of the structure keep the same mesh. This capability appeared in the earliest time and made FLUX a highly renowned software for motor design.

1994:

Eddy currents effects in a linear actuator.

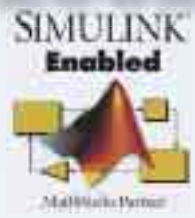
The methods developed by Mr. Marc JARNIEUX through his Ph.D. for the modelling of electromagnetic launcher are introduced in FLUX (collaborative work between *LEG, DRET* and *ISL*). It enables to take into account the linear motion in 2D models thanks to a remeshing technique of the air gap as well as sliding mesh from bottom to top to avoid mesh deformation and insure accuracy of the results and large motion.
This linear motion model was used immediately for the large market of linear actuators, at a time where speed vs. eddy current was one of the major improvement required.

1996:

Multi-position on a magnetic coupling.

The methods develop by Mr. Remy PERRIN-BIT and Mr. Thomas DREHER though their Ph.D. for the 3D modelling of magnet motors are introduced in FLUX (collaborative work between *CEDRAT, LEG, Moulinex* and *Valeo*). The main improvement of this method was to enable the 3D rotating motion by introducing the sliding cylinder. The remeshing technique is replaced by a sliding interface (cylinder placed in the air gap) on which the nodes are doubled: one belonging to the air "attached" to the rotor, the other belonging to the air "attached" to the stator. The procedure to set the motion up is described in the *first article* of this *"motion story"* and applied by Lappeenrenta University for cogging torque computation in the *second article.*

2002:



Direct co-simulation between FLUX and Matlab/Simulink® for 2D applications.

CEDRAT offers the possibility to lead transient co-simulation with Matlab/Simulink® taking into account electrical supply, motion (linear and rotating), corresponding effects (saturation, eddy currents, non linearities) and complex control scheme. This performance remains a true innovation in the field of electromagnetic design, recognized through a fruitful partnership with *The Mathworks Corp.* Applications of this coupling (transformers, motors, linear actuators) have been detailed in our last issues of FLUX Magazine.

2003:

Switch in dynamic behavior.

CEDRAT, under industrial contract with *Schneider Electric*, brings on the market the large motion in 3D. This contract was following the Ph.D. of Mr. Vincent LECONTE (*2000*: collaborative work between *LEG* and *Schneider Electric*) who established the advantages and drawbacks of different remeshing techniques.
The motion is obtained by a remeshing technique organized around three mechanical sets:
- The fixed mechanical set: not remeshed.
- The moving mechanical set: not remeshed, position being modified versus the mechanical equation.
- The compressible mechanical set: remeshed at each time step insuring no mesh deformation induced by the motion.

It brings the possibility to model 3D linear and rotating motion including contact.

Two more articles are presented in this *"motion story"* illustrate this new development:
- The validation with *Schneider Electric* on a contactor (comparison computation/measurement) that has lead to a new 3D translating motion tutorial (page 6).
- The application on these new possibilities to a 3D electromagnetic launcher of *ISL* (page 8).

In **1996**, thanks to the developments lead on electromagnetic launcher, FLUX offered the linear motion for 2D electromagnets models.
In **2003**, thanks to the developments lead for electromagnets, FLUX offered the linear motion for 3D electromagnetic launchers models !