Electro-Mechanical FEM Simulations With “General Motion“

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Abstract

In this work we present the coupling of MAGNETICS for SC, beeing a highly sophisticated FEM solver for electromagnetic simulations on the basis of GetDP [1], with a precise and fully integrated mechanical solver; resulting in the multiphysics solver General Motion (GM). The GM solver is smoothly integrated within the Siemens NX/SC system; thus making it possible to use the full capabilities of the NX/SC CAD system for creating and meshing of desired geometries . Due to this tight integration and the capability of the GM solver to use unstructured grids, h-refinement on unstructured is inherent to the solver in an easy-to-use fashion. Moreover, the electromagnetic part of the GM solver is capable of employing higher order basis functions thus also allowing p-enrichment.

As an example, we will demonstrate the simulation of an actuator, that consists of a coil, a magnet, a stopper and an anchor. The coil has 185 turns and a current of 3A is employed to induce a sufficient magnetic field in order to attract the anchor. Here, magnet, stopper and anchor consist of a non-linear material, i.e. a glowed steel with a non-linear B-H curve. For the EM part of the GM solver we use a Magnetoquasistatic setting, beeing

$$\nabla \times \mathbf{E} = -\frac{d}{dt}\mathbf{B} \qquad \text{and} \qquad \nabla \times \mathbf{H} = \mathbf{J}, \tag{1}$$

in combination with Ohm's Law $\mathbf{J} = \sigma\mathbf{E}$ and the material Law $\mathbf{B} = \mu\mathbf{H}$. Here, $\mathbf{E}$ and $\mathbf{H}$ are the electric and magnetic fields, respectively; $\mathbf{B}$ is the magnetic flux density; $\mathbf{J}$ is the current; σ is the conductivity; and μ is the permeability. For the Mechanical part of the solver Newtons Law of motion is used

$$\mathbf{F} = \mathrm{m}\mathbf{a}, \tag{2}$$

where $\mathbf{F}$ is the force acting on the moving part, and m and $\mathbf{a}$ are the mass and acceleration of the moving part, respectively. The coupling of the two solvers is then done via the EM forces, i.e. Lorentz forces and Reluctance forces

$$\mathbf{F}_{\mathrm{L}} = \mathbf{J} \times \mathbf{B} \quad \text{and} \quad \mathbf{F}_{\mathrm{R}} = \frac{dW}{dx}. \tag{3}$$

The obtained simulation results are in agreement with the measured data. In addition, other electro-mechanical systems, e.g. motors and generators can be simulated with the GM solver.

References

1. C. Geuzaine. High Order FEM schemes for Maxwell's equations taking thin structures and global quantities into account.. PhD Thesis, 2001.