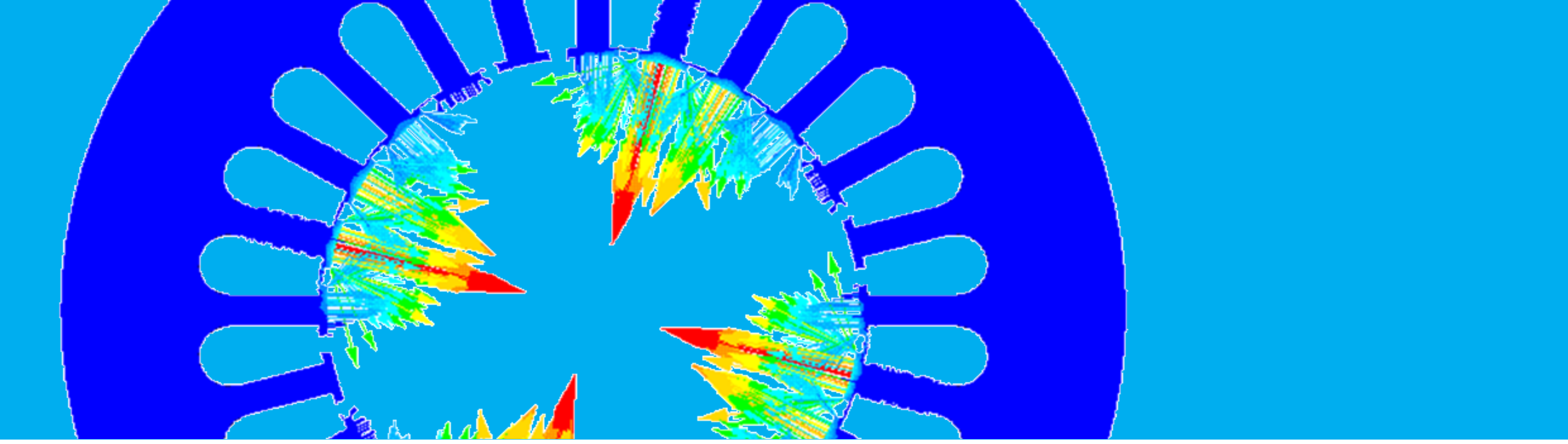


MpCCI FSIMapper
Case Study
Vibrations in Electric Motors

The FSIMapper provides advanced and robust interpolation methods to transfer electro-magnetic loads from **Infolytica MagNet** simulations onto arbitrary CSM meshes in Abaqus, ANSYS Mechanical or MSC.Nastran.

Working with Incompatible Meshes

EM and CSM usually have incompatible mesh discretizations and even non-matching geometry details. The FSIMapper can handle such non-matching model definitions – robust mapping and extrapolation methods will provide valuable results even for crucial cases.

Vibrational Analyses

Vibrational analyses such as frequency response or acoustic simulations are performed in frequency domain. The excitation is given as complex data over a frequency range.

FSIMapper provides the possibility to process transient MagNet results by Fourier transformation in order to create the corresponding loading for vibrational analyses.

Cyclic Symmetric Geometries

Due to the periodicity of electrical motors, often cyclic symmetric models are used. FSIMapper is able to map the electro-magnetic loads from a periodic section model to a full structural model.

Supported MagNet Analysis Types

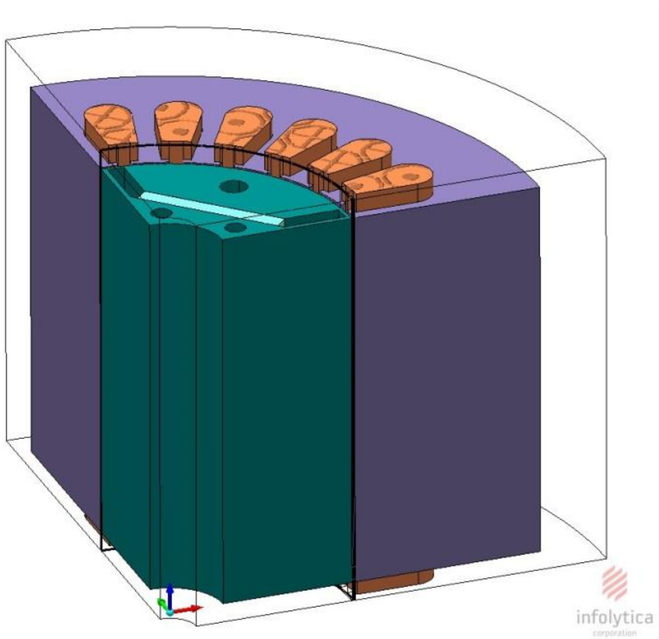
- static
- transient

Supported Target Analysis Types

- static
- transient
- harmonic

Target File Formats

- Abaqus
- ANSYS Mechanical (12.0 - 16.0)
- MSC.Nastran
- EnSight Case Gold



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Motivation and Problem Description

Electromagnetic forces in motors excite structural vibrations. They lead to material failure and to noise in the surrounding area.

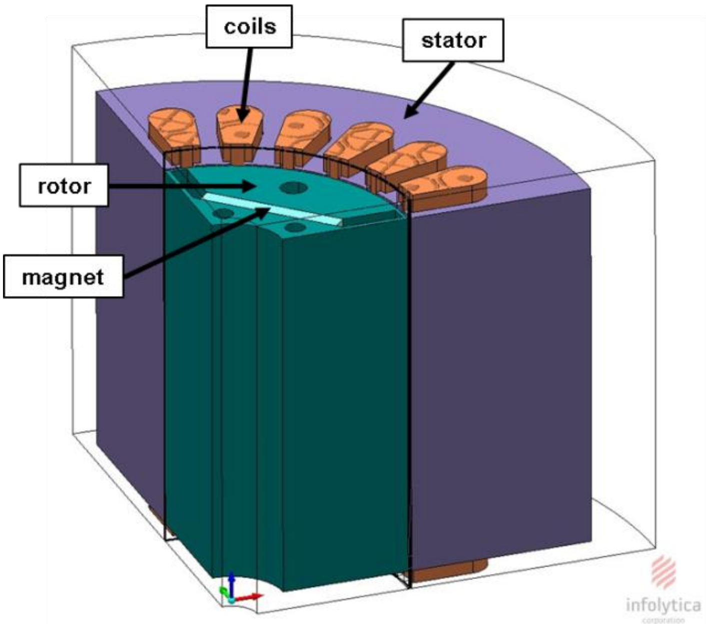
To predict vibrations in early development phases, FSIMapper provides the possibility to transfer the electromagnetic forces to structural NVH analyses.

In this case study we consider a 4-pole-24-slots electric motor, which is modelled in MagNet by a quarter section. The rotor rotates with a frequency of 30 Hz and the coils exhibit an odd parity.

We are interested in the vibrational behavior of the full stator.

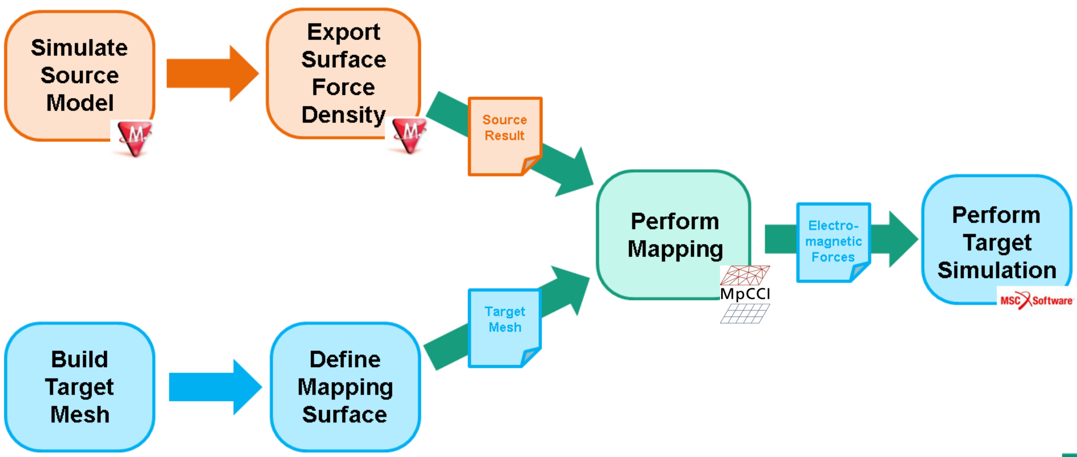
For this purpose MagNet performs a transient simulation and the results are exported into a VTK-file. FSIMapper maps the data to the target MSC.Nastran mesh and processes the data by Fourier transformation. In this way the loading for a vibrational or acoustic analysis is created.

As result FSIMapper creates an ASCII file which comprises the electromagnetic loading for a frequency response analysis in MSC.Nastran bulk data syntax. It is used in the target simulation.

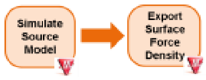


Source	
Code	Infolytica MagNet
Simulation	transient electromagnetic simulation of motor
Mesh	¼ model of motor, second order tetra elements
Target	
Code	MSC.Nastran
Simulation	frequency response analysis of stator
Mesh	full model of stator, first order hexa and penta elements

The general procedure is shown in the following flowchart.



Source Result File

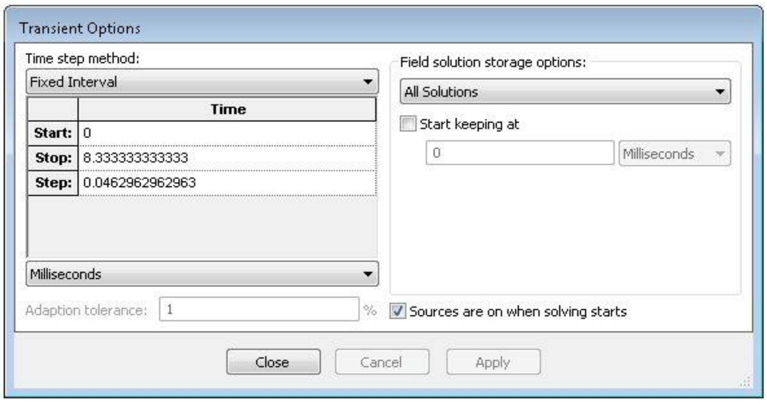


MagNet Simulation

The quarter MagNet model is simulated in the following way

- „Transient 3D with Motion“
- ¼ turn using 180 time steps
- constant time step (necessary for Fourier transformation)

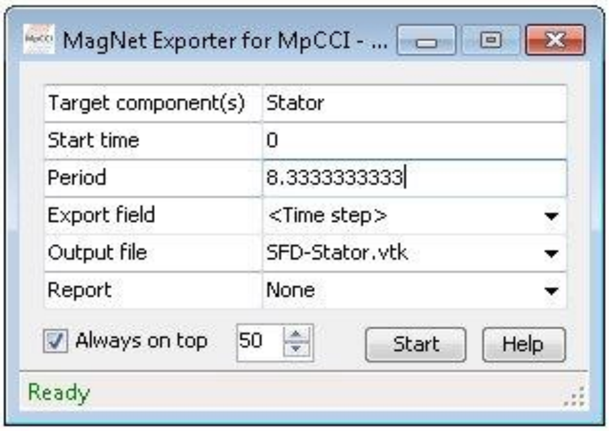
The electromagnetic forces are available for each time step as surface force density (SFD).



MagNet Export

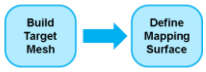
The surface force density (SFD) is exported by the MagNet „Exporter for MpCCI“:

- select the component „Stator“ from MagNet‘s object tree
- open the exporter by Extensions→Exporter for MpCCI
- put in the time span for a ¼ turn



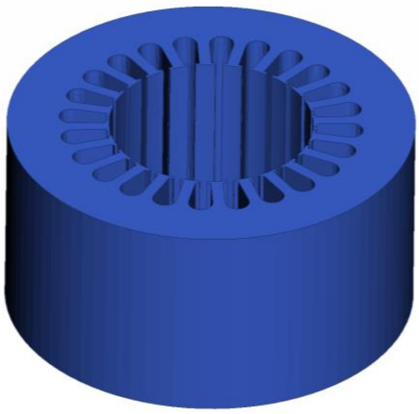
The exported *SFD-Stator.vtk* file contains the surface mesh of the stator and the SFD for 180 time steps. It is an ASCII file which can be read by FSIMapper.

Target Mesh File



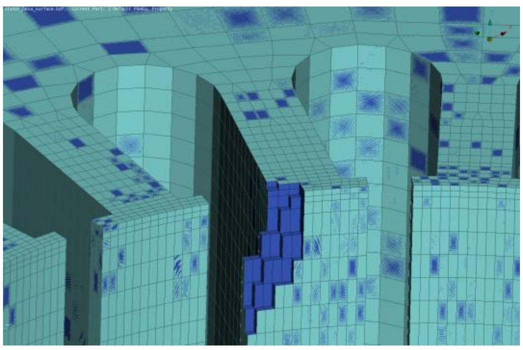
MSC.Nastran Mesh

The CSM mesh models the full stator by first order hexa and penta elements.



Mapping Surface Definition

For the mapping process, elements are created on the stator‘s surface. It is necessary that the surface elements use the same nodes as the volume mesh.



The created *stator_surface.bdf* file contains the volume and surface mesh of the stator. It is an ASCII file which can be read by FSIMapper.

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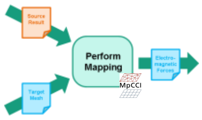


FSIMapper is an easy to use tool, which is available as GUI and in batch mode.

The GUI is subdivided into different panels where the mapping configuration is applied.

What to map

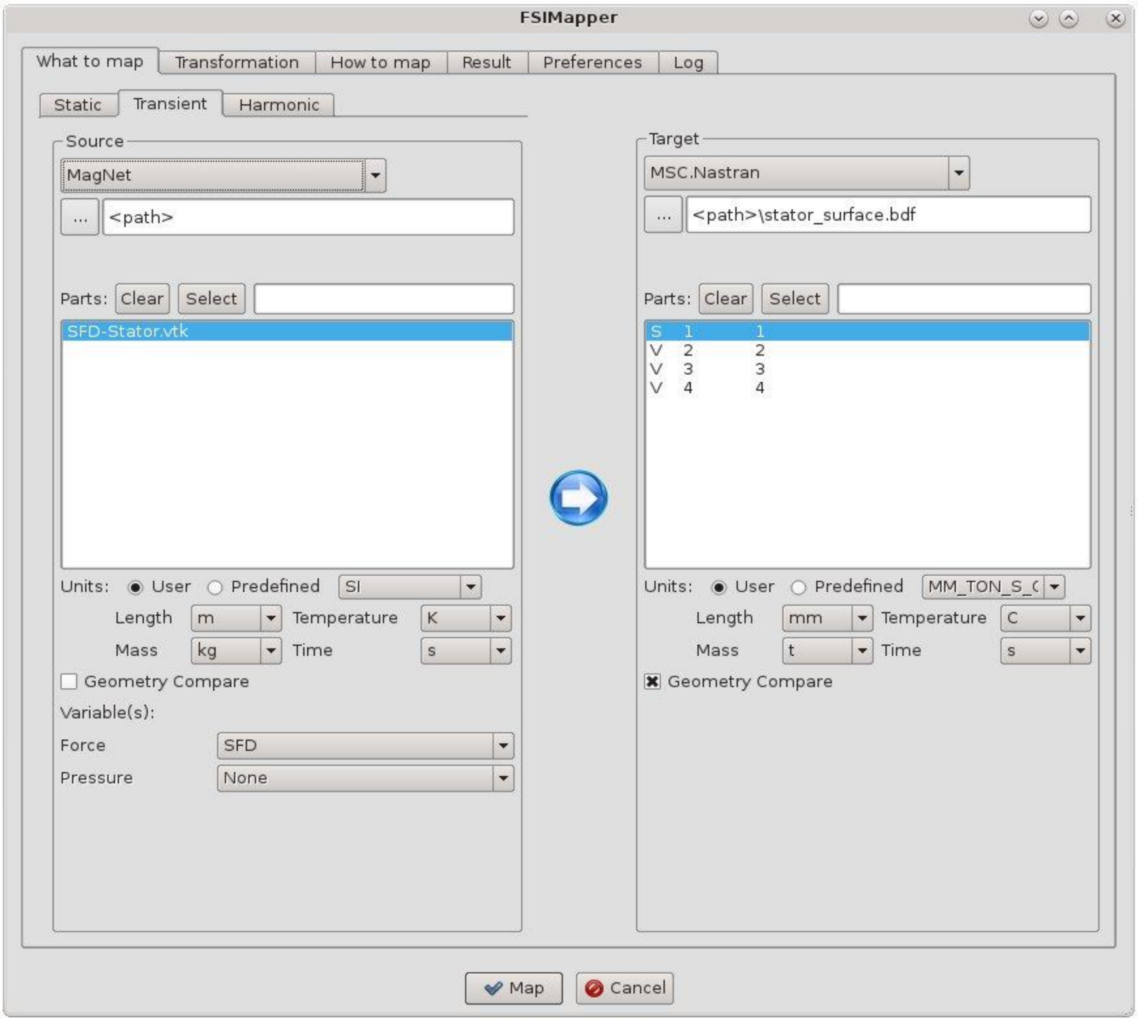
In the „What to map" panel the basic mapping information is given:

Left column „Source"

- MagNet as source simulation code
- file location of the exported *SFD-Stator.vtk* which contains the SFD
- unit system used in the VTK-file: *m-kg-s*
- SFD as force quantity

Right column „Target"

- MSC.Nastran as target simulation code
- file location of the MSC.Nastran mesh *stator_surface.bdf*
- mapping surface „S"
- unit system used in the mesh file: *mm-t-s*

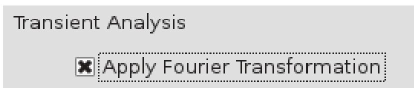


Cyclic Symmetry Transformation

Because of the periodicity of the source model, a cyclic symmetric transformation has to be applied to the mesh and the quantity. In the „Transformation" panel, all relevant information is given to create the corresponding full model.

Fourier Transformation

To convert the transient electromagnetic forces to frequency domain, as it is presumed by frequency response analyses, check „Apply Fourier Transformation" in the „Result" panel.



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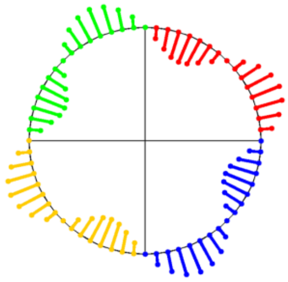
Mapping Result

Pressing the „Map“ button starts the mapping. The quarter section of the stator surface is revolved in order to create the full model.

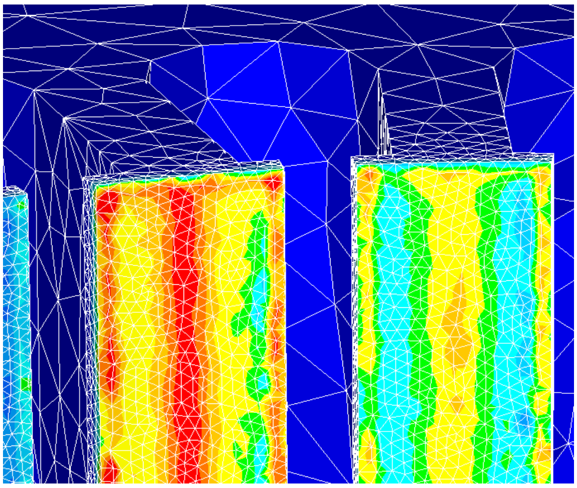
■ original MagNet surface mesh

Corresponding full model, created by FSIMapper

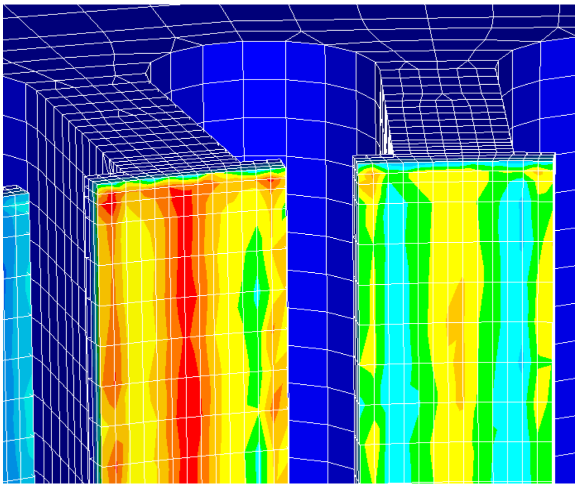


Schematical diagram of the treatment of periodic data

The SFD of all 180 time steps is mapped to the MSC.Nastran surface mesh. The MpCCI Visualizer shows the mapping quality for each time step.



SFD on MagNet source mesh

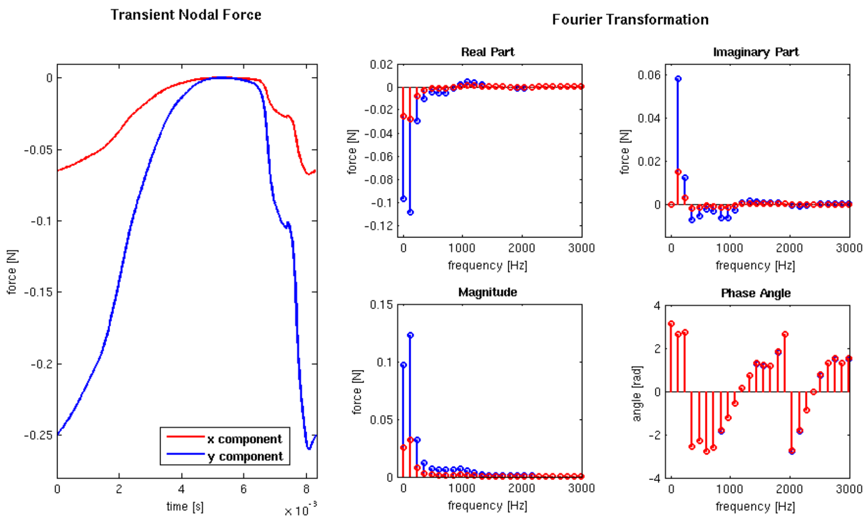


SFD on MSC.Nastran target mesh

The Fourier transformation of the transient forces is done for all surface nodes of the target mesh.

With 180 time steps the transformation results in 91 frequency components, including 0Hz which corresponds to the mean value comprised in the transient nodal force.

The force excitations (described as complex data) can be visualized for each frequency component as corresponding transient fluctuation (*stator_surface-mapped_FreqRespForce.ccvx*).



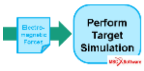
Fourier transformation of the transient nodal force at a specific node.
The Fourier Transformation figures only show frequencies up to 3000 Hz.

Electro-magnetic Forces

FSIMapper creates the file *stator_surface-mapped_FreqRespForce.bdf* including the complex nodal forces for the application in vibrational analyses.

The file is written in the MSC.Nastran bulk data syntax and can be used directly in a frequency response analysis.

Target Simulation



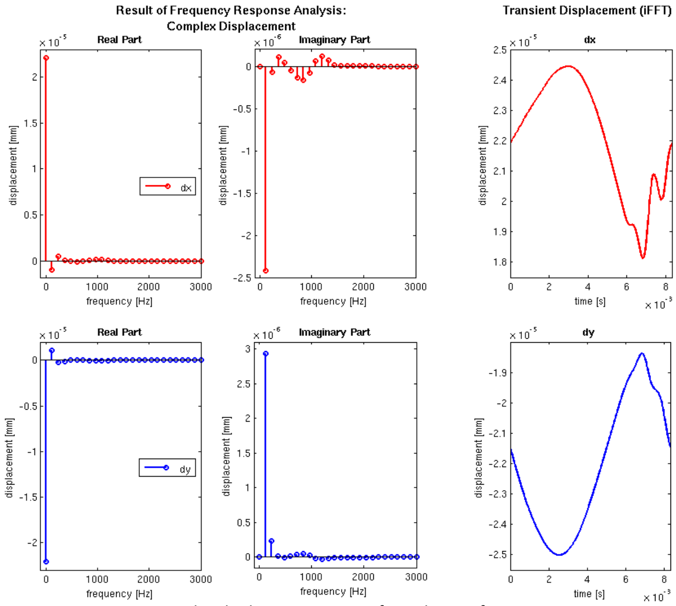
The mapping surface elements have to be excluded from the simulation since they would provide additional stiffness (→ file *stator.bdf*).

The definition of the frequency response analysis includes the FSIMapper output file using the MSC.Nastran keyword `INCLUDE`.

```
SOL 111 $ Modal Frequency Response
CEND
$
TITLE = Stator_ElectromagneticExcitation
$
  METHOD = 150
  FREQ = 601
  DLOAD = 600
  RESVEC = NO
  …
$
BEGIN BULK
EIGRL   150     -0.1    25000
$
INCLUDE stator.bdf
INCLUDE stator_surface-mapped_FreqRespForce.bdf
$
PARAM, POST, -1
ENDDATA
```

For each node a frequency dependent complex displacement vector is calculated.

Using the inverse Fourier transformation (iFFT), these data can be transferred back to the time domain.

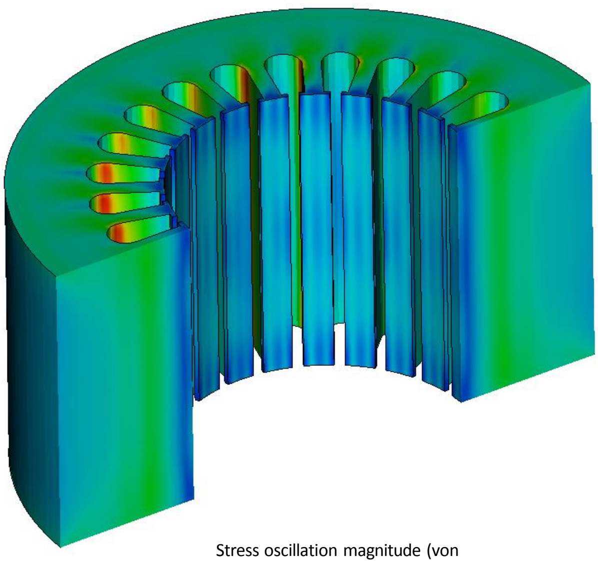


Complex displacement at specific node over frequency range.
Figures of real and imaginary part only show frequencies up to 3000 Hz.

The displacement calculated at 0Hz represents the mean deformation of the structure. At 120Hz the structural response (displacement) is the highest. The following frequencies play a decreasing role for the total vibrational response.

The frequency spectrum of stress oscillation amplitudes can be used for fatigue analyses.

Also, the acoustic response can be calculated when modelling the surrounding air.



Stress oscillation magnitude (von Mises) at 120 Hz

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