Discover the first simulation software DeDicateD to the fast electromagnetic and vibro-acoustic design of electrical machines.
MANATEE® (Magnetic Acoustic Noise Analysis Tool for Electrical Engineering) is the first simulation software dedicated to the coupled electromagnetic and vibro-acoustic design of electrical machines. Besides electromagnetic performances, the variable-speed acoustic noise and vibration levels due to 3D Maxwell forces can be calculated within a few seconds up to 20 kHz, including all the structural resonances occurring during the run-up. The efficient implementation of analytical, semi-analytical and numerical multi-physics models allows reaching the best trade-offs between calculation time and accuracy during the iterative design process of electrical machines.
Besides the efficient coupling of four multiphysical models, MANATEE includes some advanced post-processings and more than 80 predefined visualization commands, including:
- space and time waveforms, 1D and 2D Fourier Transforms
- theoretical calculation of main magnetic force harmonics (frequencies and wavenumbers)
- automated labelling of force harmonic expressions (see figure 2)
- modal participation factors at fixed speed and variable speed
- spectrograms (see figure 1) and order tracking of main magnetic forces
- harmonic removal tool and automated harmonic analysis

These tools help identifying the root causes of harmonic force generation, in order to quickly iterate and find a low-noise, low-vibration machine while achieving specified electromagnetic performances.

Moreover, some sensitivity and optimization studies can be carried on any input and output variables. A possible application is the minimization of the maximum acoustic noise level during a run-up as a function of:
- the rotor slot number in an induction machine (see figure 3)
- the pole geometry in a synchronous machine
1. ELECTRICAL MODEL

The electrical model of MANATEE includes PWM generation models and equivalent circuits with the following features:
- Import of user-defined voltage / current waveform
- Multiple PWM strategies (e.g. synchronous, asynchronous, calculated angles) (see figure 4)
- Accurate numerical calculation of slot leakage and skin effects suitable for any slot shape
- Accurate numerical calculation of saturation effects and iron losses suitable for any lamination shape
- Extended equivalent circuits to account for harmonic effects
- Coupling with FEMM for accurate calculation of the equivalent circuit parameters (e.g. magnet emf)
- Coupling with a Matlab/Simulink three-phase inverter model

2. ELECTROMAGNETIC MODEL

The flux density distribution (see figure 5) can be calculated using several methods:
- Analytical permeance / mmf and winding function model (WFM)
- Semi-analytical subdomain model (SDM)
- Magnetostatic finite-element model (FEM) based on a coupling with the open-source FEMM software (see figure 6)

As summarized in Table 1, the permeance / mmf model is a convenient way to simulate in a very short time a complex combination of physical effects such as:
- Pulse-Width Modulation (PWM)
- Saturation
- Rotor and stator skewing
- Static and dynamic eccentricities
- Uneven airgap
- Faults (e.g. short-circuit, broken bar, demagnetization)

The subdomain models are as accurate as FEM model while achieving very short computing time; they are well adapted for simple geometries without strong non-linearities.

The finite element magnetostatic model is the most accurate method and the only one suitable for non-linear electromagnetic simulation. Due to its higher calculation time, it is only recommended to simulate a single speed operating point.

The electromagnetic models of MANATEE include the following features:
- Import of user-defined air-gap flux density waveform
- Modelling of any multi-phase winding type including fractional, integral, and user-defined windings
- Fast optimized numerical algorithms
- Automated FEM post-processings
- Calculation of inductances, induced voltage, and unbalance magnetic pull
- Analytical calculation of main exciting magnetic forces frequencies and pole pair numbers

1. FEMM (Finite Element Method Magnetics) is an open-source 2D finite element software under the terms of the Aladdin Free Public License (see www.femm.info).
3. STRUCTURAL MODEL

The structural models of MANATEE include an analytical model based on an equivalent cylindrical shell accounting for teeth, winding and frame effects, and a 3D orthotropic structural model based on a coupling with GetDP finite element solver (see figure 7).

The mechanical FEM model is automatically built and solved from MANATEE inputs. The resulting modal basis can be visualized using Gmsh open source tool.

Besides the natural frequencies of the external frame (rotor or stator), the structural model calculates its dynamic radial deflections to be used in acoustic calculations. It includes the following features:

- import of user-defined modal parameters (damping, natural frequencies)
- calculation of static / dynamic displacements, velocity and accelerations (analytical model)
- automated meshing and coupling with FEA (GetDP) with different boundary conditions
- automated classification and visualization of GetDP structural modes in a user interface (see figure 8)
- Frequency Response Function calculation with GetDP
- calculation of modal participation factors at fixed speed and variable speed
- visualization of the operational deflection shapes

The analytical model gives fast results, and its limited accuracy is not an issue for variable speed applications. The FEM model takes much longer time to be solved but it is more accurate, and it can account for more effects such as cooling ducts in the yoke and special frame geometries.

4. ACOUSTIC MODEL

The acoustic solver of MANATEE is based on the efficient implementation of analytical cylindrical radiation factor (see figure 9) and directivity models of the external structure (rotor or stator). The evolution of the acoustic sound power and sound pressure levels during a full speed range, including field weakening effects, can be calculated within a few seconds on a standard laptop.

The acoustic model includes A-weighting and third octave analysis (see figure 10).

2. GetDP is an open-source finite element solver (including 3D structural mechanics) under the terms of the Aladdin Free Public License (see http://onelab.info/wiki/GetDP).

3. Figure 7: stator lamination mesh with GetDP/Gmsh

4. Figure 8: modal basis calculated with the finite element model GetDP

5. Figure 9: cylindrical radiation factor model

6. Figure 10: third-octave sound power level spectrum

ANYTHING MISSING?

OUR TEAM CAN IMPLEMENT ADDITIONAL FEATURES UPON REQUEST, AND HALF A DAY OF SOFTWARE DEVELOPMENT IS OFFERED WITH A NEW MANATEE LICENSE.
MANATEE documentation includes:

- tutorials on different topologies
- HTML documentation of all MANATEE functions, inputs, and outputs
- schematics and description of all MANATEE input variables
- description of all available post-processings
- validation cases of the different modules

EOMYS delivers single-user perpetual licences of MANATEE on USB dongle keys. Any new licence includes half a day of customized software development. As MANATEE is made of several modules (asynchronous & synchronous machines, coupling with FEMM, etc.), each module licence can be bought separately. For a detailed quotation, please send us an email at manatee@eomys.com.

EOMYS can deliver customized trainings on noise and vibration due to magnetic forces and on the application of MANATEE simulation software to the optimal electromagnetic and vibro-acoustic design of your specific electrical machine.

We provide technical support at manatee@eomys.com or by phone from Monday to Thursday, 9:30 to 12:00 and 14:00 to 16:00 at +33 (0)9 81 36 63 46.