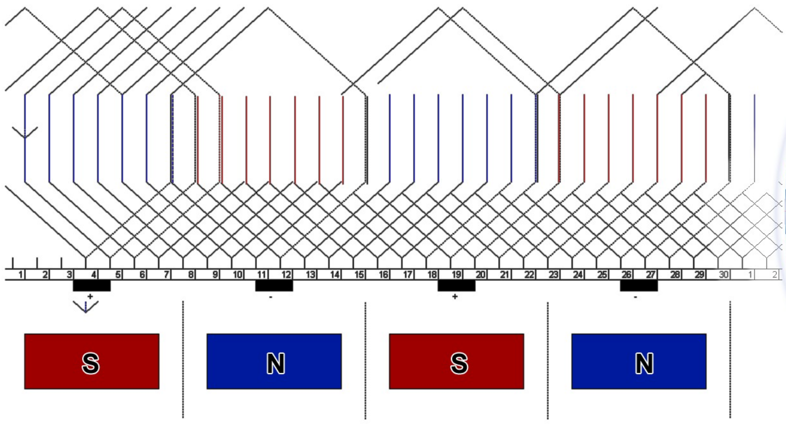
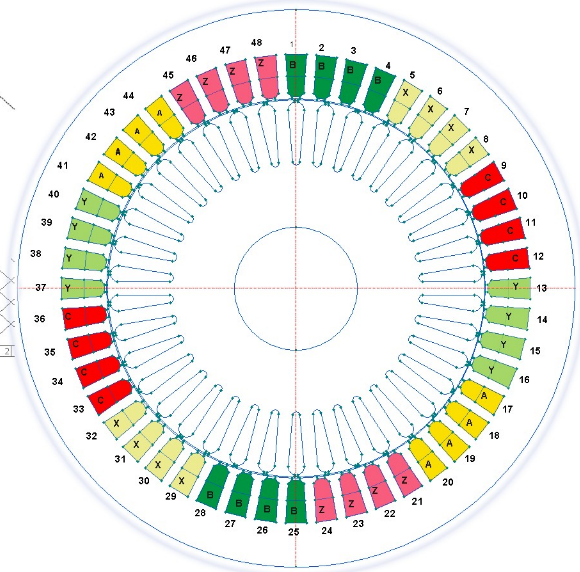
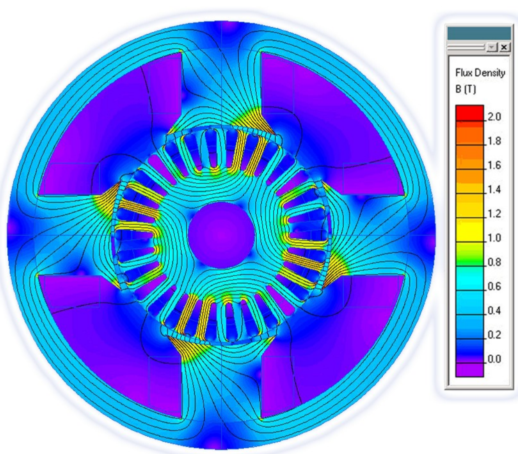
Electric machines simulation with QuickField

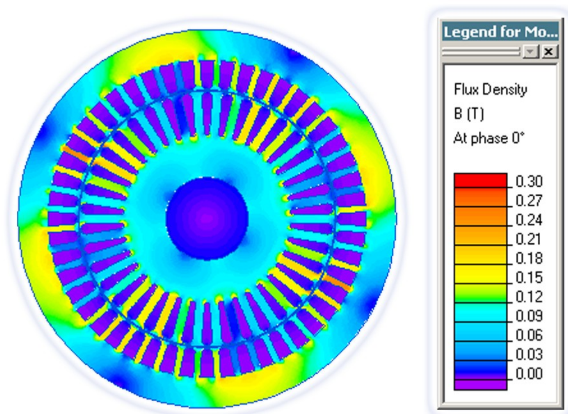
Practical recommendations for practical engineers.

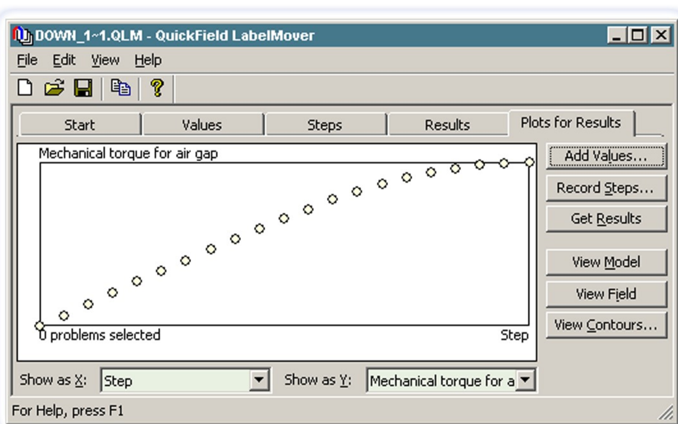
(corresponding QuickField examples are placed to *ICEM 2011/motors* folder in the root of your QuickField Demo CD)

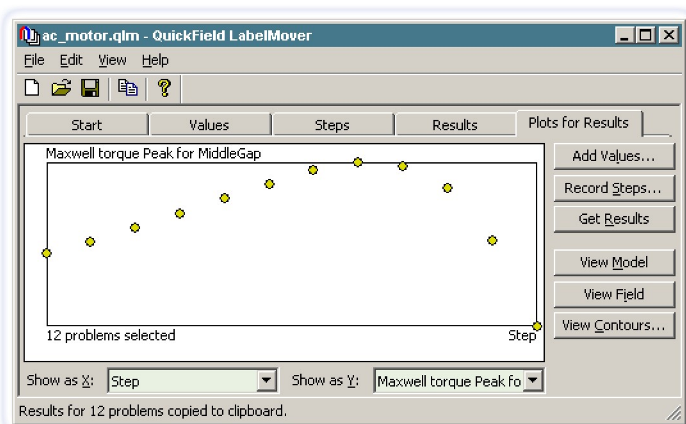












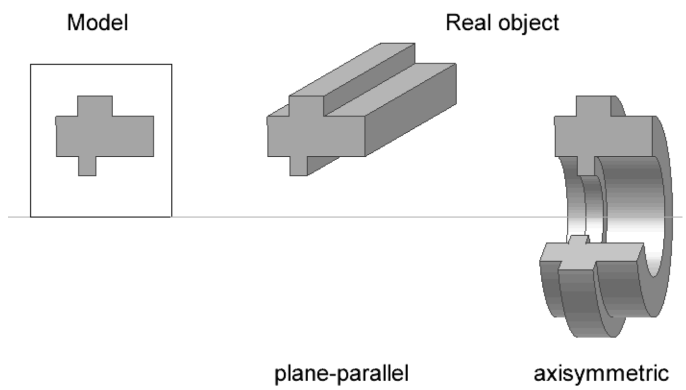
Tera-Analysis Ltd.

There are three main steps for the electric machine simulation in QuickField:

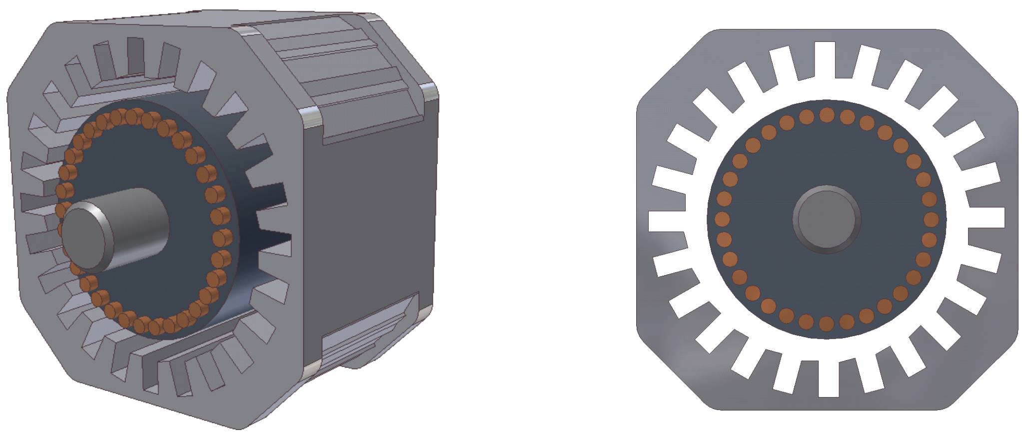
1. **Geometry definition**
2. **Defining the field sources (currents or permanent magnets) and material properties.**
3. **Results analysis.**

1. Geometry definition

QuickField may solve plane-parallel or axysimmetrical tasks.



Roughly speaking, rotating machine is formed by two coaxial objects – rotor inside, and stator outside. If the axial length is not too small compared to the diameter, then the system may be represented as a plane-parallel model.



Real device Simulation model

Using this approach, 2D analysis may often be applied for the simulation of the active zone of electric machine – i.e. the part which generates the torque, defines the current loads and flux densities. End zones of electric machine usually require 3D simulation, and can not be performed with QuickField.

2. Field sources and material properties.

Main modules of QuickField used for electric machine analysis are magnetostatics, AC magnetics and transient electromagnetics.

- **Magnetostatics** may be applied for the models with non-linear magnetic materials, and permanent magnets. Provides calculation of fluxes, torques, forces.
- **AC Magnetics** provides field analysis for the models with sinusoidal source currents of any frequency (up to MHz range), with eddy currents in solid conductors. But there should be only one frequency for all values in the model, and therefore all the materials should be considered as linear. This formulation provides the same outputs as Magnetostatics, plus possibilities for impedance calculation
- **Transient Electromagnetics** expands all features and approaches of the Magnetostatics to the time domain. Supports linear and non-linear materials, formula-defined sources, and is most flexible for wide range of problems. But transient analysis calculations are most time-consuming of all types of QuickField analysis, because require field calculation in many time steps.

Other QuickField modules may also be useful for additional studies. For example, Transient Heat Transfer module may be used for calculation of the temperature distribution, Mechanical Stresses may help to estimate the mechanical stability, and DC Conduction – for the calculation of the currents in the slot insulation

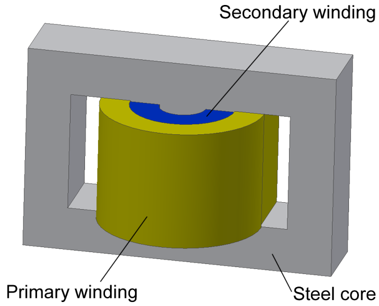
3. Results analysis

Results, provided by QuickField, include local values, field maps, plots and integrals in any moment of time (in Transient problems) or phase (in AC problems)

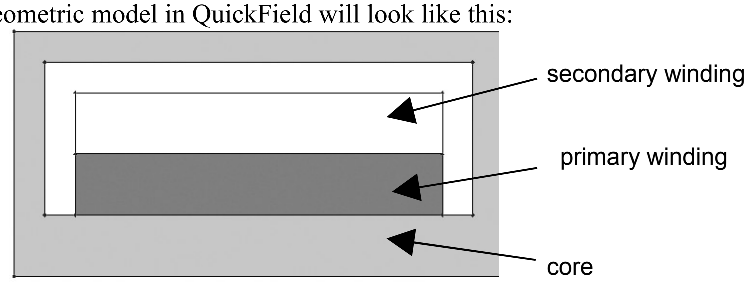
How to model transformers with QuickField

Axysimmetrical problem:	**Plane-parallel problem**:
Single phase transformer with concentric windings	*Most of other types of transformers (including 3-phase). End zone effects should be neglected, which may affect the accuracy.*

Example. Single phase shell-core transformer.

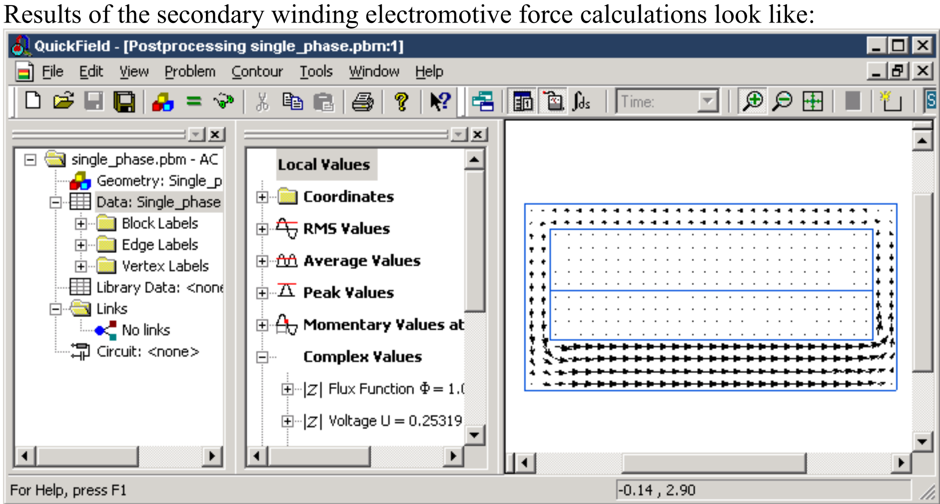


Geometric model in QuickField will look like this:



Windings are put concentrically one over another. The thin wire filling the winding is represented by the current layer.

Results of the secondary winding electromotive force calculations look like:



To find the actual value of the secondary winding voltage the displayed parameter should be multiplied by the number of the secondary winding turns. This gives the secondary winding voltage with no load:

$200 \cdot 0.253 = 50.6$ V.

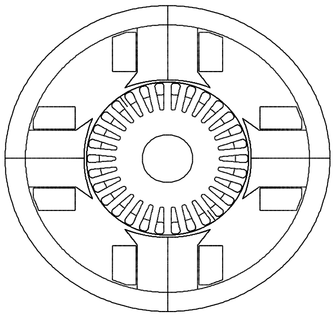
Please, refer to the QuickField problem in the “transformers” folder.

How to model DC motors with QuickField

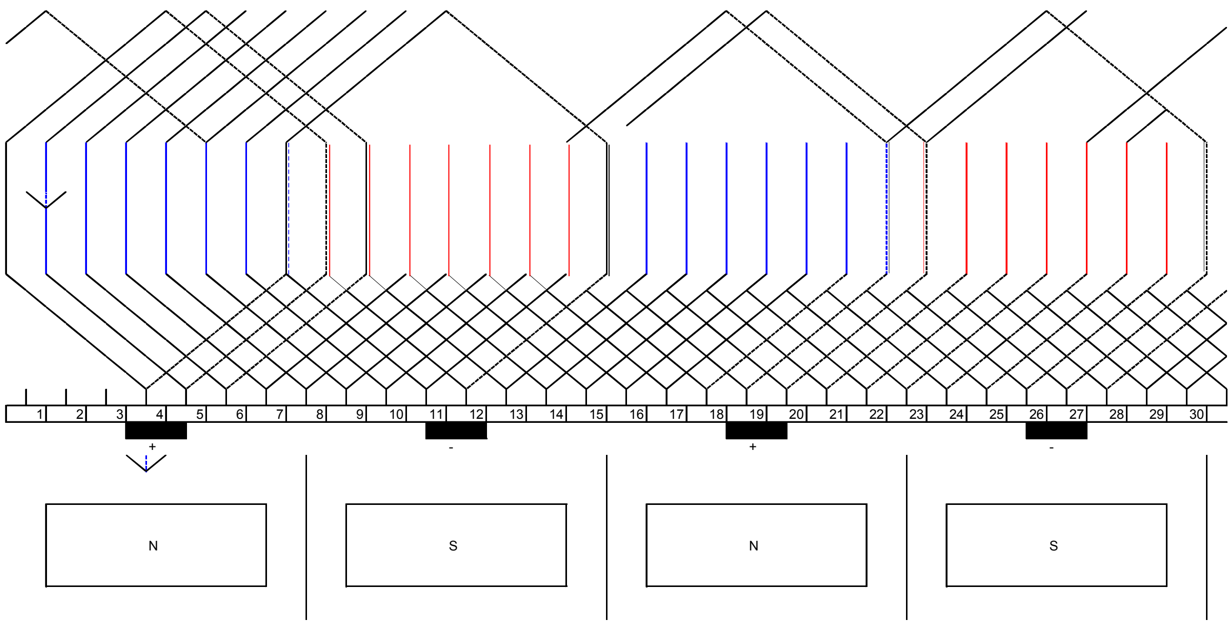
In DC motor the stator poles produce static magnetic field. The rotor field is also static because the brushes are fixed. Two static fields may be simulated in DC Magnetics.

Example: Calculate the current-torque caracteristic for the motor with serial excitation winding.

Geometric model looks like:

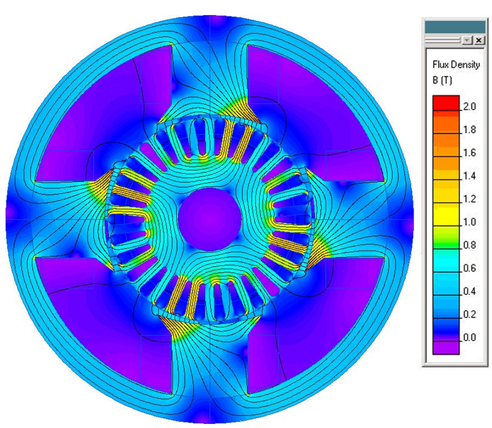


The labels of the direct and reverse currents of the core were set according to the connection schema:

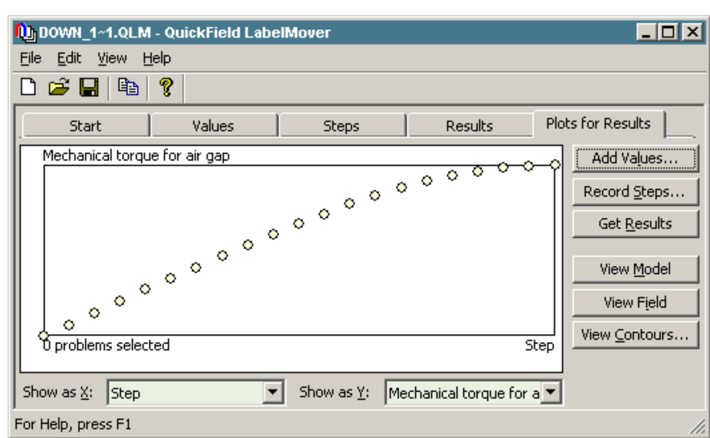


Winding in the rotor slots is defined by the equivalent single conductor. This simplification does not affect to the magnetic field distribution. All conductors with the same direction of currents are assigned the same label. Label properties specify serial connection of the conductors.

Resulting magnetic field:



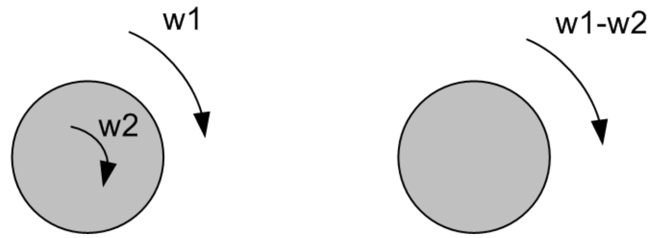
Current-torque caracteristic:



Please, refer to the QuickField problem in the “dc_motor” folder

How to model asynchronous motors with QuickField

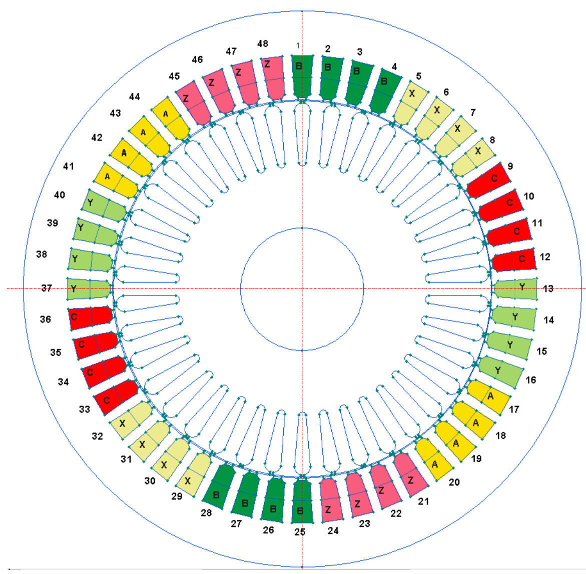
To simulate rotation the" slip frequency" approach should be used.



The problem with different rotation speeds of the rotor (w2) and magnetic field of the stator(w1) may be replaced by the problem with stationary rotor and the stator field rotating with (w1 - w2) speed.

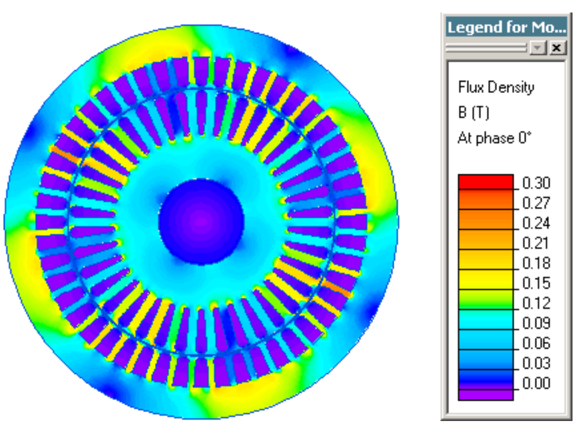
Example: Calculation of the torque-speed characteristic of the motor M(n)

On the geometric model below the block labels, showing the phases of the windings, are shown

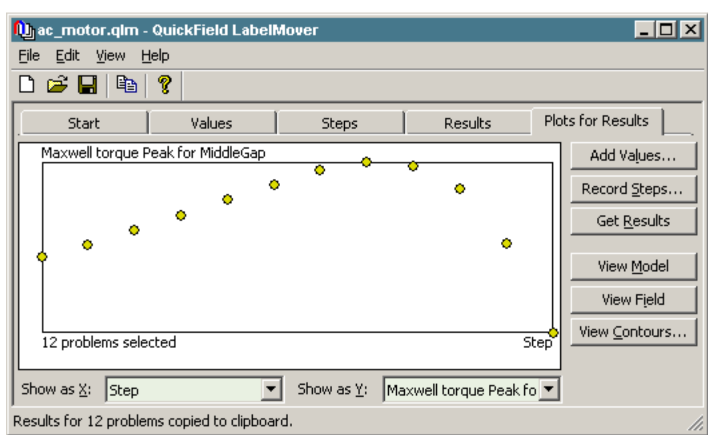


Series of the calculations with the varied stator current frequency gives the torque-speed characteristic. For this task combined use of QuickField with LabelMover is recommended:

Resulting magnetic field:



Torque-speed characteristic



Please, refer to the QuickField problem in the "ac_motor" folder.

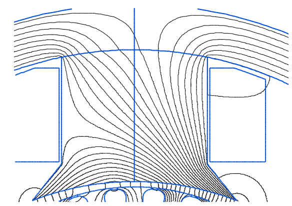
How to model different parts of electric machines in QuickField

Hints for the typical tasks of electric motor design are provided below.

Slot

In most cases there is no need to draw all individual conductors. They may be replaced by single solid conductor, or, if there are several layers of winding – by several conductors.

Pole



Pole winding consists of many conductors. This decreases eddy current effects, and it may be supposed that the current density is uniformally distributed along the cross section of the winding. Such winding may be presented in QuickField by a single block with evenly distributed current density.

Laminated cores

There is no eddy currents in laminated cores. Electrical conductivity in the block properties should not be defined.

Non-linear magnetic materials may be defined in the DC magnetics or Transient electromagnetics.

Short-circuited loops

Short circuited loops may be defined by setting U=0 in the label properties. I=0 means that the loop is disconnected.

Short-circuited rotor

Short-circuited rotor may be presented in QuickField as a set of conductors, having the same label, and with U=0 in this label properties.

Rotating magnetic field

Rotating magnetic field may be simulated either in AC Magnetics or in Transient Electromagnetics. AC magnetics requires definition of the single frequency for all currents in the problem, and setting of specific phases for every current. Transient Electromagnetics allowing using formulas for currents definition, e.g. sin(t+120).

External circuit

AC magnetics and Transient electromagnetics in QuickField supports connection of the external circuit, and coupled simulation of the field and circuit parts of the problem.

Heating of stator and rotor

QuickField supports coupled problems of AC magnetics (or Transient Electromagnetics) with Heat Transfer. Currents calculated in the conductors by electromagnetic simulation may then be used as heat sources in the thermal analysis.

Mechanical deformations and stresses in the electric motor parts

Coupled magneto-mechanical analysis may be applied to calculate deformations and stresses in the parts of electric motors. Magnetic forces, calculated by electromagnetic simulation are then considered as a mechanical loads in the Stress Analysis.

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