1-1: Introduction to the Opera-3d software

OPERA-3d

• What is OPERA-3d?
• Structure of the package
  - History
• Solution modules
  - TOSCA
  - ELEKTRA
  - SCALA
  - CARMEN
  - SOPRANO
  - TEMPO
  - DEMAG
  - QUENCH
  - STRESS
OPERA-3d

- Software package for the design of electromagnetic products and devices
  - Three dimensional
  - Finite element based
    - most commonly used numerical method for solving continuum physics problems
  - Developed by Vector Fields based on algorithms originated at Rutherford Appleton Laboratory, UK

Structure of OPERA-3d

- Modeller
- Pre-Processor
- Solvers
  - TOSCA, ELEKTRA, SCALA, CARMEN, SOPRANO, TEMPO, DEMAG, QUENCH, STRESS
- Post-Processor
Pre-processing

- **Modeller**
  - Geometric modelling
  - CAD data input and output
  - Automatic meshing
  - Connection to external circuit
  - Launches Analyses and Post-Processor
  - Windows / Motif based

- **Pre-Processor**
  - Extrusion based modelling
  - Automatic and mapped meshing
  - Launches analyses (not DEMAG, STRESS or QUENCH)

Solvers

- **TOSCA**
  - Magnetostatics
  - Electrostatics
  - Current flow

- **Examples**
  - Magnetic resonance imaging magnets
  - Motors and generators
  - Actuators
  - Cathodic protection
  - Switchgear
Solvers

- **ELEKTRA**
  - Time varying fields with eddy currents
    - Steady state AC
    - Transient
    - Velocity

- **Examples**
  - Induction heating
  - Magnetic recording
  - Pipeline inspection
  - Transformers
ELEKTRA - currents in coil supports

Solvers

**SCALA**
- Electric fields with space charge limited particle beams
  - Thermionic emission
  - Field effect emission
  - User defined emission
  - Emission from plasmas
- Imposed magnetic fields
- Secondary emission

**Examples**
- X-ray tubes
- Flat screen displays
- Ion sources
X-Ray tube in SCALA

Solvers

- **CARMEN**
  - Time varying fields with rotational or linear motion
    - Eddy currents
    - Non-linear materials
    - Coupling to circuits
    - Mechanical coupling
    - Co-simulation with Simulink™

- **Examples**
  - Motors and generators
  - Position sensors
  - Actuators
Axial flux motor in CARMEN

Solvers

• **SOPRANO**
  - High frequency electromagnetic fields
  - Full wave equation
    • Steady state AC (defined frequency)
    • Eigenvalue (modal analysis)
  - EV also in Concerto

• **Examples**
  - Resonant cavities
  - EMC
Resonant cavity in SOPRANO

Solvers

- **TEMPO**
  - Temperature distribution (Steady State or Transient)
    - Stand alone thermal analysis
    - Heat sources may be imported from other OPERA modules
    - Temperatures may be exported to other OPERA modules

- **Examples**
  - Induction heating and annealing
  - Rotating machine temperature rise
  - Heating due to eddy current braking
Annealing automotive axle in TEMPO

Solvers

• DEMAG
  - Modelling of magnetization process in permanent magnets
    • Residual magnetization pattern
  - Transient eddy current analysis
  - Export of magnetization to other solvers

• Examples
  - Magnetizing fixture design
  - Biased ferrites in microwave structures
Remanent field strength after magnetizing

Solvers

• QUENCH
  - Modelling of superconducting quench
  - Transition between superconducting and normal state
  - Transient thermal analysis
  - Coupled to electric circuit and magnetic fields

• Examples
  - MRI / NMR magnets
  - Particle accelerator magnets
2 concentric solenoids in QUENCH

Solvers

- **STRESS**
  - Mechanical small deformation simulation
  - Elastic limit of materials
  - Anisotropic and orthotropic materials
  - Stand alone analysis with applied loads
  - Body forces imported from electromagnetic simulations
  - Thermal expansion / contraction
    - Temperature distribution from TEMPO

- **Examples**
  - MRI / NMR magnets
  - Electrical machine windings
  - Transformers
Deflection of steel plate due to field from pot core

Post-processing

- Computing useful results for the designer
  - Fields
  - Currents
  - Forces and torque
  - Energy and power
  - Particle trajectories
  - Harmonics
  - Temperature

- Export results to other software
  - Tables

- User programmable