Model based systems engineering - software tools for design and measurements for HFM

Roxie

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ROXIE - Matthias Bonora

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- Release of Roxie23
- Scripting and interfaces
- Prototyping
- MBSE, product cycle engineering



New Roxie23 features

- Technical improvements
 - Dynamic memory allocation
 - Improved Iron and Mesh Generator
 - Structured XML output generation
 - Python API for communication with ROXIE
 - Containerization
- Coil geometries
 - CCT magnets
 - Wigglers and Undulators, Flex PCBs
 - Custom discretisation, for coil ends and straight section
 - Curved magnets
- Analysis settings
 - Zonal harmonics for solenoid design
 - K-values of search coils
 - Maxwell stress tensors
 - Quench Simulation (Adiabatic, 2.5D)



3D coil geometry macros





CCT coil macro



Higher-order multipoles



Transformations



Pitch variation at the ends









Darboux frame Frenet frame hard way

Frenet frame soft way



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Curved Magnets

- On any geometry
- Simple curved Iron
- Special case CCT











Technical Improvements

- Dynamic Memory Allocation
- Discretization per block
 - 30 elements in straight section
 - 25 elements in coil heads
 - 1500 elements in CCT coils

Structured XML output





Improved Iron file editor



Hook into optimization loop (WIP)



- Use of external meshes
 - *.hmo
 - *.hmascii (Hypermesh)





Scripting and Interfaces

- Python API: <u>roxie-api</u>
 - Input file handling
 - Load existing files
 - Update tables, change flags
 - Output file handling
 - Parsing of XML output
 - Generation of plots/tables
 - Execution
 - Run ROXIE from python script
 - Execute on remote machine (REST)



Example galery

Below is a gallery of examples for using this package

Output parsing and plotting

Examples using the output parsing and plotting functionality



Scripting and Interfaces

- Fully self-contained Docker Image
 - Terminal + Remote desktop (GUI)
 - Rest API for programmatic access
 - Runs on any machine
- ROXIE Interfaces package: <u>roxie-interfaces</u>
 - Collection of scripts and tools for IO file translation
 - Roxie output to step file (End spacers)
 - Mesh files to Roxie hmo

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Prototyping Platform

- Prototype new functionality in Python
- Fast turnaround; integrate once matured
 - Core code
 - Script
- Examples:

HFM

High Field Magnets

• <u>RoxCCT</u>, Eddy current solver



Eddy current solver

Differential geometry generation module, example CCT (python API)







Figure 1: Conductor peak fields in curved CCT magnets. Left: constant pitch. Right: Pitch faded in the magnet ends.



Model Based Systems Engineering

- Multiple Domains, Tools, Data Sources
- Complex information exchange

- Magnet Design as a system of domain models
 - Each model within its domain
 - Constraints, inputs, dependencies, sources
- Models as base of information exchange
 - Artefacts, queries
 - Repeatable, traceable, adaptable



Model Based Systems Engineering

- pyMBSE, self-contained multi-model execution
 - different models (geometry, magnetic, mechanic)

Magnet.data

Magnet.iron

Single repository

Mechanical model

Load geometry

Setup Ansvs

Call Ansys

Plot results

Report

Collect inputs

Collect Ansys

Collect Geometry

Collect Magnetic

· Assemble report

Magnetic model

Call Roxie

Plot results

· Load geometry

Setup simulation

Geometry model

· Load inputs

Calculate

Plot results

· define geometry

Cross-dependencies

Research and Technology

MagNum

dependent execution



MMBSE

Database with Magnets / Systems

- Different models for a magnet
- Cover design process
- Define checks, verification
- REST API to access models
 - Inputs/Outputs
 - Reports
 - Versions
 - Scriptable

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CERN Exchange

PSI Exchange

Secure exchange

Summary - Outlook

- Re-established know-how to develop ROXIE
 - Core extensions
 - Interfaces (python, scripting, data)
 - Platform for integrating new features (ROXIE core or scripts)
 - Interdependend model execution
- Next steps
 - Magnet Database, Magnet Design Workflow
 - Eddy current integration in Xroxie
 - HTS
 - Ease of use





High Field Magnets

Links

- Roxie: <u>https://roxie.docs.cern.ch/</u>
- Roxie-Api: <u>https://roxie-api.docs.cern.ch/</u>
- Roxie-interfaces: <u>https://roxie-interfaces.docs.cern.ch</u>

