Development of an application for management of material properties for superconducting magnet modelling

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About me

- Youssef Raouyane, 23 years old

- 2nd year engineer student in l’Institut Supérieur d’Informatique, de Modélisation et de leurs Applications, Clermont-Ferrand, France

- Specialization: Scientific Computing and Modelling

- 2018: Internship in Michelin: Management of a database of tire test results
  - Development of a GUI to extract data from the database (C#)
  - Development of a set of functions to put the tests results in the database after each test (VBA)

- Short-term internship program in CERN
Outline

1. Main goals of the internship

2. Application for automatic testing of material properties

3. Development of a SWAN Notebook for quench load calculation
Main goals of the internship

• Extension of an existing material properties library in C for S.C magnet modelling
• Development of a testing suite program for the functions of this library
• Creation of documentation for the users
• Development of a notebook to calculate the hot-spot temperature
Use these dlls in MATLAB

Use these dlls in COMSOL

Tasks to do

Complete the material properties library functions in a way that they can be loaded in MATLAB & COMSOL

- Develop scripts to compile source files into dlls.
- Develop a test suite to perform unit tests, and compare the output values of C to the MATLAB material properties library.
- Provide a user manual that explains all the steps from GITLAB to COMSOL or MATLAB
- Develop a reference web page for all the material properties functions

Workflow

GitLab

MATLAB

COMSOL

STEAM member

The material properties functions implementation conform to the formulas given in Giulio Manfreda, Review of ROXIE’s Material Properties Database for Quench Simulation.
Comparison of material property calculation in MATLAB and C

• All input parameters describing material properties in C (as dlls) and MATLAB are stored in a JSON

• Unit tests are performed in MATLAB

• For each *material property* function:
  - Load the *dll* in MATLAB
  - Check if all the functions required by COMSOL exist in the current *dll*
  - Check if all the errors are thrown by the *dll* in the case of incorrect inputs
  - Compare the output values with the outputs of the equivalent MATLAB function
  - Display the name of the functions that don’t have the same outputs with MATLAB
  - Unload the *dll* from MATLAB ➔ Next *dll*

• All the methods required for these tests are contained in a class: **UnitTestDLL**
Added material properties functions

• 36 new material properties functions added (thermal conductivity, specific heat, etc.)

• Formulas are mainly based on the reference document [1]

• All material properties functions can be loaded and then used in COMSOL as well as with any other programming language (C, C++, JAVA, MATLAB, etc.)

Contents:

• Main definitions

• Tutorial on all the steps to follow from GITLAB to test the material properties functions in MATLAB (i.e. modifications to do in the machine and in the JSON file)

• Use of a dll / material property function standalone in MATLAB

• Use of a dll / material property function standalone in COMSOL

• Tutorial on all the steps to follow to add a new material property function (source code structure, JSON file modification, HTML code modification in the material property webpage)
• Development of a web page as a reference of all the material properties functions that we have in the STEAM repository
• Development carried out using HTML5 (HyperText Markup Language)
• The web page contains for each material, the properties that we can calculate with the range of validity of calculation, the reference, the plot of the function and the output unit

URL: https://espace.cern.ch/steam/_layouts/15/start.aspx#/SitePages/Material%20Properties.aspx
Main goal:
Develop a simple MIITs calculator in order to facilitate the dimensioning of a quench protection based on the energy extraction system.

Implementation carried out in Python using PyCharm.

Unit tests to compare output values with a COMSOL model.

Implementation of two classes containing only static methods.

### MaterialProperties

<table>
<thead>
<tr>
<th>Function/Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>cv_cu_nist</code></td>
<td>(real) : real</td>
</tr>
<tr>
<td><code>cv_cu</code></td>
<td>(real) : real</td>
</tr>
<tr>
<td><code>rho_cu_cudj</code></td>
<td>(real) : real</td>
</tr>
<tr>
<td><code>cv_nbti</code></td>
<td>(real) : real</td>
</tr>
<tr>
<td><code>calculate_specific_heat</code></td>
<td>(array, array, real, real, real, real) : array</td>
</tr>
<tr>
<td><code>get_json</code></td>
<td>(char) : dictionary</td>
</tr>
<tr>
<td><code>get_func_information_json</code></td>
<td>(char, char) : dictionary</td>
</tr>
<tr>
<td><code>initialize_parameters</code></td>
<td>(char, char) : array</td>
</tr>
</tbody>
</table>

### Notebook

<table>
<thead>
<tr>
<th>Function/Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>calculate_discharge</code></td>
<td>(real, real, real, real, real, real, real) : real</td>
</tr>
<tr>
<td><code>calculate_b_busbar</code></td>
<td>(Array, real) : Array</td>
</tr>
<tr>
<td><code>res_bus_bar_normal</code></td>
<td>(Array, Array, real, real, real, real) : real</td>
</tr>
<tr>
<td><code>calculate_i_busbar</code></td>
<td>(Array, real, real) : Array</td>
</tr>
<tr>
<td><code>calculate_hot_spot_temperature</code></td>
<td>(real, array, real, real, real, Pandas.Series, real, real, real) : Pandas.Series</td>
</tr>
<tr>
<td><code>calculate_quench_load</code></td>
<td>(real, real, real, real, real, real) : Array</td>
</tr>
<tr>
<td><code>sweep_on_rea</code></td>
<td>(real, real, real, real) : Array</td>
</tr>
</tbody>
</table>
Calculation of a MIIIts curve

- Good agreement between STEAM-BBQ and notebook
- Notebook can be used to select an energy extraction resistor to keep temperature and voltage to ground below desired limits
Summary

- Extension of material properties library for simulating electro-thermal phenomena in S.C magnets
- Testing suite program to perform unit tests
- Documentation: User guide + Summary web page
- Swan Notebook for dimensioning the energy extraction system