

HYSTERSOFT – Software for the simulation of magnetization processes

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Abstract

Students often have difficulty understanding the phenomena underlying magnetization processes or the simulation of electric circuits in which the inductor is made of hysteretic ferromagnetic materials. HysterSoft is a complex, yet user-friendly software that allows users to numerically implement various phenomenological models of hysteresis, such as the Energetic, Jiles-Atherton, Hodgdon, and numerous Preisach-type models of hysteresis. This software can also be used to analyze and simulate electronic circuits such as nonlinear RL and RLC circuits consisting of hysteretic inductors. HysterSoft can be used for both research and educational activities, as well as for the development of other phenomenological models of hysteresis.

Simulation of magnetic hysteresis in phenomenological models

HysterSoft is a program for the simulation of hysteresis phenomena in magnetic materials. The goal of HysterSoft is to provide a user-friendly simulation framework in which various phenomenological models of hysteresis can be implemented by the users. The program comes with a few models already installed, but other models of hysteresis can also be easily added to the framework. Once a new model is added, for instance by writing a script file that describes the main equations of the model, HysterSoft is able to plot and analyze various magnetization processes or to describe the behavior of electronic circuits containing hysteretic inductors (for instance RL or RLC circuits in which the inductor is made by using a magnetic material which has hysteresis).

The HysterSoft framework was created to help students, engineers, material scientists, and researchers become familiar with and understand some of the current issues in the analysis, modeling, and simulation of hysteresis phenomena in magnetic materials. With the help of HysterSoft we can:

- Simulate various magnetization processes when the applied magnetic field is given. The user can define the applied magnetic field analytically or input different values at runtime.
- Simulate electronic circuits, such as RL or RLC circuits containing hysteretic inductors.
- Simulate rate/frequency-dependent magnetization processes. So far, two dynamic models of hysteresis have been implemented in HysterSoft: the effective-field and relaxation-time approximation models.
- Simulate aftereffect phenomena in magnetic materials. The aftereffect phenomena can be simulated by using the Monte-Carlo approach.
- Compute the First-Order Reversal Curves (FORCs) under different operating conditions (e.g. at different frequencies).
- Identify the parameters of the models by using experimental FORC data (in the case of the Preisach Model) or parameters on the major hysteresis loop (for other models).
- Simulate temperature and stress-dependent magnetization processes in magnetic materials (for now, implemented only for the Energetic model).
- Simulate inverse magnetic problems (i.e. computation of the magnetic field when the magnetization is given a-priori).

Model Implementation

HysterSoft was initially developed as a simulation environment for the Energetic Model of hysteresis. The program proved to be a useful tool for the simulation of magnetization processes in hysteretic materials and, later on, the Preisach, the Jiles-Atherton, and the Hodgdon models were added to the program. Currently, HysterSoft supports most models of hysteresis in which the output variable can be expressed as a function of the input variable in algebraic, differential, or integral form. A few models of hysteresis already come with the installation kit and other models will be added in the near future. The models currently included in the installation kit are:

- The Energetic Model
- The Hodgdon Model
- The Jiles-Atherton Model
- The Langevin Model
- The Classical Preisach Model
- The Generalized Preisach Model
- The Moving Preisach Model

In the case of the Preisach Models, the Preisach distribution function can be given analytically as a bivariate function, or numerically in a data file.

What Models Can Be Added to HysterSoft?

Most scalar hysteresis models in which the magnetization or the magnetic moment can be computed numerically when the magnetic field is given can be implemented in HysterSoft. The magnetization or the magnetic moment should be expressed in the form of an algebraic, differential, or integral equation of the magnetic field. For instance, in the case of the Energetic Model, the magnetization can be expressed as an algebraic equation of the magnetic field. In the case of the Jiles-Atherton and Hodgdon Models of hysteresis, the magnetization can be written as a differential equation of the magnetic field, while in the case of Preisach-type models, the magnetization can be expressed in integral form. These equations should be specified in a script file that should be copied in the installation directory of HysterSoft. Every time HysterSoft starts the script files are loaded by the simulation framework and placed in the “Scalar Models” menu.

New models can be easily added to HysterSoft by using script files. The script files should provide the analytical expression of the magnetic susceptibility as a function of current and past values of the magnetization and magnetic field. This feature of HysterSoft can be very useful for testing and developing new phenomenological model of hysteresis.

Software Installation and New Models Incorporation

HysterSoft can be installed on the following operating systems: Windows 2000, Windows 98, Windows ME, Windows NT, Windows XP. To install HysterSoft you need to download and install the HysterSoft setup file which can be found at www.eng.fsu.edu/~pandrei/HysterSoft [3]. It is strongly recommended that you install the latest version since, usually, that is the most stable one.

The latest version of HysterSoft (HysterSoft 1.5) was released in August 2006 and has undergone significant improvements from earlier versions. Specifically:

- The model identification techniques for the Energetic models were improved considerably.
 - Electronic circuits comprising of inductors with hysteretic materials can be simulated by using dynamic models of hysteresis.
 - Added capabilities to implement other models of hysteresis with the help of script files.
 - Improved graphic interface.
 - First-Order Reversal-Curve (FORC) analysis can be easily carried out in the framework of any model implemented in HysterSoft. By using the FORCs, HysterSoft can identify the FORC diagram (Preisach function).
 - The Discrete Preisach Model (i.e. the generalized moving Preisach model in which the distribution function is given numerically) was implemented.

- HysterSoft functions can be called externally by using the HysterSoft library. For instance, HysterSoft can be called from Matlab, Fortran, C++, Java, or other languages. The Assisted Test window (see figure 4) allows the user to resolve in a period of unlimited time a version of a test from a chapter, generated by the computer. The right answer version is immediately posted allowing the candidate to learn quickly. The evaluation can be made in any moment.

Future development

In the future we plan to add new features which will improve considerably the area of applicability of HysterSoft. These features include:

- Better graphical interfaces and data manipulation features.
- Debug possibilities when running script files.
- Increased circuit simulation flexibility. For now, HysterSoft can simulate only RL and RLC circuits with hysteretic inductors. In the next version of HysterSoft, the circuit will be designed by the user at runtime.
 - The ability to work with vector models of hysteresis. So far, HysterSoft can work only with scalar models of hysteresis, but in the future it will be improved to also work with vector models of hysteresis. This feature will allow us to implement the 3-D Energetic Model, Vector Preisach-type models, and some micromagnetic models such as Landau-Lifshitz-type models.
 - Implementation of more electronic devices containing magnetic materials (e.g. transformers and actuators).
 - Direct communication with experimental devices. For instance, HysterSoft will communicate directly with Vibrating Sample Magnetometers (VSM) or other optical or low temperature magnetometers.
 - Detailed documentation files.

Conclusions

HysterSoft is a powerful program that students and researchers can use to gain knowledge related to the analysis, modeling and simulation of magnetic materials. Users can analyze how magnetization curves are influenced by various parameters of the material, such as the demagnetizing factor, particles dimensions, coercivities and the interaction field in particulate magnetic materials, as well as by external conditions, such as the stress level and temperature. HysterSoft can also be used to study strongly nonlinear electronic circuits consisting of hysteretic inductors and nonlinear components. Through HysterSoft's user-friendly interface one can easily simulate complex magnetization processes in magnetic materials, which would otherwise require long and expensive experimental procedures.

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