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# A phenomenological mathematical model of hysteresis

J. Takács

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**Keywords:** *Hysteresis, Mathematical modeling*

**Abstract:** *This paper starts with the description of a purely mathematical model of the saturation curve and the hysteresis loop based on the fundamental similarities between the Langevin function the specified  $T(x)$  function and the sigmoid shape. The  $T(x)$  function which is composed of tangent hyperbolic and linear functions with its free parameters can describe the regular hysteretic magnetisation curve. Developed from this function the model describes not only the regular hysteresis loop but also the biased and other minor loops like the ones produced by the interrupted and reversed magnetisation process and the open "loops" created by a piecewise monotonic magnetising field input of diminishing amplitude. The remanent magnetism as the function of the interrupted field co-ordinates is predicted by the model in this mathematical form for the first time. The model presented here is based on the principle that all processes follow the shape of the  $T(x)$  function describing the shape of the major hysteresis loop of the ferromagnetic specimen under investigation. The model is also applicable to hysteretic processes in other fields.*

## Introduction

The mathematical description of the hysteresis is one of the fundamental problems of ferromagnetism. The investigation into the phenomenon produced a number of approaches, like the Preisach model (accommodation, wiping out property, moving model, vector model etc.), vector hysteresis based on Stoner-Wohlfarth model, each contributing to the understanding of the phenomenon without creating the full picture of it.

Ferromagnetic substances are generally solids, characterised by two important properties, namely the Curie point and also that the atoms of these materials have large dipole moments. When the sample is subjected to an external magnetic field the domains tend to align in the direction of the field and by doing so the volume of the domains with moments in the direction of the field will increase. When the field is removed not all the domains will move back to their original random state. The overall state of the sample will be different from that of the beginning and this is the magnetic history called hysteresis. When the external field is large the magnetisation is no longer proportional to the applied field and tends to a constant saturation value. A general overview of the different hysteresis models can be found in *Hysteresis Models in Electromagnetic Computation* by Iványi (1997).

A number of mathematical approaches had been made to formulate the behaviour of ferromagnetic substances. One of the first theories was put

The author is indebted to Professors A.J. Moses, J.G. Booth and K. O'Grady for their valuable suggestions and comments on the manuscript.

# Mathematics Of Hysteretic Phenomena The Tx Model For The Description Of Hysteresis

**Hamid Reza Noori**



## **Mathematics Of Hysteretic Phenomena The Tx Model For The Description Of Hysteresis:**

*Mathematical Reviews* ,2001      *Physics Briefs* ,1994      **Hysteresis Phenomena in Biology** Hamid Reza Noori,2013-12-31      **The Science of Hysteresis** ,2006 Volume 1 covers P Mathematical models P Differential equations P Stochastic aspects of hysteresis P Binary detection using hysteresis P Models of unemployment in economics P PVolume 2 covers P Physical models of magnetic hysteresis P All aspects of magnetisation dynamics P PVolume 3 covers P Hysteresis phenomena in materials Over 2100 pages rich with supporting illustrations figures and equations P Contains contributions from an international list of authors from a wide range of disciplinesP Covers all aspects of hysteresis from differential equations and binary detection to models of unemployment and magnetisation dynamics      **Mathematical Models of Hysteresis** ,1991 The research described in this proposal is currently being supported by the US Department of Energy under the contract Mathematical Models of Hysteresis Thus before discussing the proposed research in detail it is worthwhile to describe and summarize the main results achieved in the course of our work under the above contract Our ongoing research has largely been focused on the development of mathematical models of hysteretic nonlinearities with nonlocal memories The distinct feature of these nonlinearities is that their current states depend on past histories of input variations It turns out that memories of hysteretic nonlinearities are quite selective Indeed experiments show that only some past input extrema leave their marks upon future states of hysteretic nonlinearities Thus special mathematical tools are needed in order to describe nonlocal selective memories of hysteretic nonlinearities Our research has been primarily concerned with Preisach type models of hysteresis All these models have a common generic feature they are constructed as superpositions of simplest hysteretic nonlinearities rectangular loops Our study has by and large been centered around the following topics various generalizations and extensions of the classical Preisach model finding of necessary and sufficient conditions for the representation of actual hysteretic nonlinearities by various Preisach type models solution of identification problems for these models numerical implementation and experimental testing of Preisach type models Although the study of Preisach type models has constituted the main direction of the research some effort has also been made to establish some interesting connections between these models and such topics as the critical state model for superconducting hysteresis the classical Stoner Wohlfarth model of vector magnetic hysteresis thermal activation type models for viscosity magnetostrictive hysteresis and neural networks      **Models of Hysteresis** Augusto Visintin,1993      **Mathematical Models of Hysteresis . Progress Report No. 4, January 1, 1991--December 31, 1991** ,1991 The research described in this proposal is currently being supported by the US Department of Energy under the contract Mathematical Models of Hysteresis Thus before discussing the proposed research in detail it is worthwhile to describe and summarize the main results achieved in the course of our work under the above contract Our ongoing research has largely been focused on the development of mathematical models of hysteretic nonlinearities with nonlocal memories The distinct feature of these nonlinearities is that

their current states depend on past histories of input variations. It turns out that memories of hysteretic nonlinearities are quite selective. Indeed, experiments show that only some past input extrema leave their marks upon future states of hysteretic nonlinearities. Thus, special mathematical tools are needed in order to describe nonlocal selective memories of hysteretic nonlinearities. Our research has been primarily concerned with Preisach type models of hysteresis. All these models have a common generic feature: they are constructed as superpositions of simplest hysteretic nonlinearities, rectangular loops. Our study has by and large been centered around the following topics: various generalizations and extensions of the classical Preisach model; finding of necessary and sufficient conditions for the representation of actual hysteretic nonlinearities by various Preisach type models; solution of identification problems for these models; numerical implementation and experimental testing of Preisach type models. Although the study of Preisach type models has constituted the main direction of the research, some effort has also been made to establish some interesting connections between these models and such topics as the critical state model for superconducting hysteresis, the classical Stoner-Wohlfarth model of vector magnetic hysteresis, thermal activation type models for viscosity, magnetostrictive hysteresis, and neural networks.

**Mathematical Analysis of the Hysteresis Loop as a Basis for Attrition Phenomena** Irvin Whiteman, 1957     Hysteresis José Carlos Dias, 2014

The study of complex hysteresis problems has become increasingly important in recent years since the hysteresis phenomenon affects significantly the decisions that have to be rendered in a wide range of real world practical applications. For example, the so-called hysteresis effects may influence substantially some fields not directly related to the natural sciences such as finance, economy, or fiscal policy. In addition, such phenomenon is also typically present in many engineering and physics applications of interest such as in magnetism, spin valve technology, semiconductors, surface physics, aeronautical and civil engineering, aerodynamics, complex battery systems, biology, etc. This book focuses on the most recent attempts for modeling a diverse variety of complex hysteresis problems faced in economics, engineering, and physics. The chapters of this book provide a self-contained, rigorous, and clear treatment of the different types and sources of hysteresis under a large spectrum of applications. The book also highlights how stochastic control and other mathematical tools, as well as econometric techniques, can be applied for analyzing the complex properties of hysteresis problems. This authoritative book is a definitive guide on how to understand the newest designs for modeling hysteresis in highly complex systems, and thus it will be an essential reading for graduate students and researchers in economics, engineering, and physics.

*Hysteresis* José Carlos Dias, 2014-07-04

The study of complex hysteresis problems has become increasingly important in recent years since the hysteresis phenomenon affects significantly the decisions that have to be rendered in a wide range of real world practical applications. For example, the so-called hysteresis effects may influence substantially some fields not directly related to the natural sciences such as finance, economy, or fiscal policy. In addition, such phenomenon is also typically present in many engineering and physics applications of interest such as in magnetism, spin valve technology, semiconductors, surface physics,

aeronautical and civil engineering aerodynamics complex battery systems biology etc This book focuses on the most recent attempts for modeling a diverse variety of complex hysteresis problems faced in economics engineering and physics The chapters of this book provide a self contained rigorous and clear treatment of the different types and sources of hysteresis under a large spectrum of applications The book also highlights how stochastic control and other mathematical tools as well as econometric techniques can be applied for analyzing the complex properties of hysteresis problems This authoritative book is a definitive guide on how to understand the newest designs for modeling hysteresis in highly complex systems and thus it will be an essential reading for graduate students and researchers in economics engineering and physics

*Hysteresis Phenomena* Rufus A. Andrews,1924      **The Science of Hysteresis** Bozzano G Luisa,2005-12-20 The Science of Hysteresis      Hysteresis Effects and Dynamics of Phase Transitions in Shape Memory Materials with Differential-Algebraic Models R.V.N. Melnik,2018 The dynamics of phase transitions and hysteresis phenomena in materials with memory is described by a strongly nonlinear coupled system of partial differential equations which in its generality can be solved only numerically Following principles of extended thermodynamics in this paper we construct a new model for the description of this dynamics based on the Cattaneo Vernotte law for heat conduction Models based on the Fourier law follow from this general consideration as special cases We develop a general procedure for the solution of the resulting systems by their reduction to differential algebraic systems Finally a computational code for the numerical implementation of this procedure is explained in detail and representative numerical examples are given      **The Science of Hysteresis: Mathematical modeling and applications** ,2006      *A Mathematical Model for Hysteresis* Michael Negin,1965

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