Modelling Phase Change In A 3d Thermal Transient Analysis

BEST DASHAWN

The Random-Cluster Model Springer Science & Business Media
Provides a comprehensive coverage of the basic phenomena. It contains twenty-five chapters which cover different aspects of boiling and condensation. First the specific topic or phenomenon is described, followed by a brief survey of previous work, a phenomenological model based on current understanding, and finally a set of recommended design equa

MODELING OF THE PHASE CHANGE MATERIAL OF A HYBRID STORAGE USING THE FINITE ELEMENT METHOD Springer Science & Business Media
The book provides an introduction to the physics which underlies phase transitions and to the theoretical techniques currently at our disposal for understanding them. It will be useful for advanced undergraduates, for post-graduate students undertaking research in related fields, and for established researchers in experimental physics, chemistry, and metallurgy as an exposition of current theoretical understanding. - ;Recent developments have led to a good understanding of universality; why phase transitions in systems as diverse as magnets, fluids, liquid crystals, and superconductors can be brought under the same theoretical umbrella and well described by simple models. This book describes the physics underlying universality and then lays out the theoretical approaches now available for studying phase transitions. Traditional techniques, mean-field theory, series expansions, and the transfer matrix, are described; the Monte Carlo method is covered, and two chapters are devoted to the renormalization group, which led to a break-through in the field. The book will be useful as a textbook for a course in `Phase Transitions', as an introduction for graduate students undertaking research in related fields, and as an overview for scientists in other disciplines who work with phase transitions but who are not aware of the current tools in the armoury of the theoretical physicist. - ;Introduction; Statistical mechanics and

thermodynamics; Models; Mean-field theories; The transfer matrix; Series expansions; Monte Carlo simulations; The renormalization group; Implementations of the renormalization group. -

Boundary Element Methods for Heat Transfer with Phase Change Problems Springer

The random-cluster model has emerged as a key tool in the mathematical study of ferromagnetism. It may be viewed as an extension of percolation to include Ising and Potts models, and its analysis is a mix of arguments from probability and geometry. The Random-Cluster Model contains accounts of the subcritical and supercritical phases, together with clear statements of important open problems. The book includes treatment of the first-order (discontinuous) phase transition.

Quantum Ising Phases and Transitions in Transverse Ising Models Springer Nature

Phase Change with Convection: Modelling and ValidationSpringer

Energy Storage in Phase-change Materials Cambridge University Press

During the operation of phase-change ink-jet printers a bubble formation phenomenon often occurs. These bubbles are detrimental to the operation of the printer and substantial efforts are made to remove them. The objective of this research was 1: to develop a fundamental understanding of how bubble or void formation occurs during the phase-change process, and, 2: to develop a simple computer model to simulate this behavior which can then be used as a tool for better design of print-head geometries. Preliminary experimental work indicated the void formation to be a result of the density change accompanying the phase-change process. The commercial numerical code, Flow 3-D, was used to model the phase-change process in print-head geometries and substantiate certain simplifying assumptions. These assumptions included the effect of convection on the process and the effect of the varying material properties. For channel sizes less than 0.5 cm the phase-change process was found to be a pure conduction process. Convection effects are thus negligible and can be eliminated from the model. The variability of density, specific heat and thermal conductivity must be included in the model, as they affect the phase-change process dramatically. Specific heat is the most influential of the properties and determines, along with the conductivity, the rate at which the phase change takes place. The density must be included since it is directly linked to the void formation.

Phase Change with Convection: Modelling and Validation Springer Science & Business Media

Predictive theories of phenomena involving phase change with applications in engineering are investigated in this volume, e.g. solid-liquid phase change, volume and surface damage, and phase change involving temperature discontinuities. Many other phase change phenomena such as solid-solid phase change in shape memory alloys and vapor-liquid phase change are also explored. Modeling is based on continuum thermo-mechanics. This involves a renewed principle of virtual power introducing the power of the microscopic motions responsible for phase change. This improvement yields a new equation of motion related to microscopic motions, beyond the classical equation of motion for macroscopic motions. The new theory sensibly improves the phase change modeling. For example, when warm rain falls on frozen soil, the dangerous black ice phenomenon can be comprehensively predicted. In addition, novel equations predict the evolution of clouds, which are themselves a mixture of air, liquid water and vapor.

Phase Transitions Birkhäuser

... "What do you call work?" "Why ain't that work?" Tom resumed his whitewashing, and answered carelessly: "Well. lI1a), he it is, and maybe it aill't. All I know, is, it suits Tom Sawvc/: " "Oil CO/lll!, IIOW, Will do not mean to let 011 that you like it?" The brush continued to move. "Likc it? Well, I do not see wlzy I oughtn't to like it. Does a hoy get a chance to whitewash a fence every day?" That put the thing ill a Ilew light. Ben stopped nibhling the apple .... (From Mark Twain's Adventures of Tom Sawyer, Chapter II.) Mathematics can put quantitative phenomena in a new light; in turn applications may provide a vivid support for mathematical concepts. This volume illustrates some aspects of the mathematical treatment of phase transitions, namely, the classical Stefan problem and its generalizations. The in- tended reader is a researcher in application-oriented mathematics. An effort has been made to make a part of the book accessible to beginners, as well as physicists and engineers with a mathematical background. Some room has also been devoted to illustrate analytical tools. This volume deals with research I initiated when I was affiliated with the Istituto di Analisi Numerica del C.N.R. in Pavia, and then continued at the Dipartimento di Matematica dell'Universita di Trento. It was typeset by the author in plain TEX.

The Random-Cluster Model Springer

In recent decades, latent heat storage in phase change materials (PCMs) received considerable attention. This is due to their high latent heat capacity, which is essentially required for managing and overcoming the temporal mismatch between energy supply and demand. Thus, at the time of energy availability at supply side, it is stored in PCMs so as to be extracted later on when it is needed. In order to provide continuous operation, there are some periods when a thermal storage has to be simultaneously charged and discharged. Most studies focused either on charging, discharging, or consecutive charging and discharging process, while limited work has been conducted for the case of simultaneous charging and discharging (SCD). The first objective of this dissertation is to develop a numerical model to analyze the heat transfer mechanism within a horizontal PCM storage under SCD. Since the possible heat transfer mechanisms within PCMs are conduction, convection or a combination of both, two models are used to identify the mechanism under SCD; i.e. the pure conduction (PC) model and combined conduction and natural convection (CCNC) model. The PC model is a hypothetical model, which neglects the natural convection during phase change process; however, the CCNC model is the real case one. Validation of the model results by comparison with experimental data shows an acceptable agreement both under melting and solidification. Therefore, the developed model can be used to numerically study the phase change process in PCMs.Natural convection is the result of density changes, which create buoyancy forces within melted PCM and plays a significant role during melting. Currently, the most widely used method to account for natural convection is the effective thermal conductivity method. The method considers an artificial increase in thermal conductivity values to take into consideration the effect of natural convection by comparing the results with experimental data. Two major shortcomings of this method are that first, it is tedious to obtain the proper value and second, the method does not provide information about the melting front location. In this dissertation, a novel simplified front tracking method is presented to replace the thermal conductivity method. The novel method is based on considering two separate melting fronts for the upper and lower halves of a horizontal thermal storage system. Therefore, two dimensionless correlations are developed to map the results of the simple PC model to that of the complicated CCNC model based on the presented logic. The method essentially creates a link between CCNC and PC models, which is also missing in the literature. Based on verification, the

correlations can provide results within ±15% discrepancy.
Models in Statistical Physics and Quantum Field Theory Clarendon Press
This book provides an introduction to nonequilibrium statistical physics via lattice models. Beginning with an introduction to the basic driven lattice gas, the early chapters discuss the relevance of this lattice model to certain natural phenomena and examine simulation results in detail. Several possible theoretical approaches to the driven lattice gas are presented. In the next two chapters, absorbing-state transitions are discussed in detail. The later chapters examine a variety of systems subject to dynamic disorder before returning to look at the more surprising effects of multiparticle rules, nonunique absorbing-states and conservation laws. Examples are given throughout the book, the emphasis being on using simple representations of nature to describe ordering in real systems. The use of methods such as mean-field theory, Monte Carlo simulation, and the concept of universality to study and interpret these models is described. Detailed references are included.
Simultaneous Charging/Discharging of Phase Change Materials Springer Science & Business Media
This monograph introduces breakthrough control algorithms for partial differential equation models with moving boundaries, the study of which is known as the Stefan problem. The algorithms can be used to improve the performance of various processes with phase changes, such as additive manufacturing. Using the authors' innovative design solutions, readers will also be equipped to apply estimation algorithms for real-world phase change dynamics, from polar ice to lithium-ion batteries. A historical treatment of the Stefan problem opens the book, situating readers in the larger context of the area. Following this, the chapters are organized into two parts. The first presents the design method and analysis of the boundary control and estimation algorithms. Part two then explores a number of applications, such as 3D printing via screw extrusion and laser sintering, and also discusses the experimental verifications conducted. A number of open problems and provided as well, offering readers multiple paths to explore in future research. Materials Phase Change PDE Control & Estimation is ideal for researchers and graduate students working on control and dynamical systems, and particularly those studying partial differential equations and moving boundaries. It will also appeal to industrial engineers and graduate students in engineering who are interested in this area.
Modeling and simulation of complete liquid-vapor phase change process inside porous media Nova Publishers
To increase the efficiency of energy-intensive industrial processes, thermal energy storages can offer new possibilities. A novel approach is investigated in the project HyStEPs. In this concept, containers filled with PCM are placed at the shell surface of a Ruths steam storage, to increase storage efficiency. In this work, a two-dimensional model using the finite element method is developed to simulate the PCM of the hybrid storage as designed in the HyStEPs project. The apparent heat capacity method is applied in a MATLAB implementation, considering heat transfer by both conduction and natural convection. This successfully validated code can handle any desired layout of materials arranged on a rectangular domain. Furthermore, a parameter study of different dimensions and orientations of the PCM cavity was conducted. The impact of natural convection was found to lead to significantly varying behaviour of the studied cavities with different orientation during the charging process, while it was found to be negligible during the discharging process.
Mathematical Modeling Of Melting And Freezing Processes World Scientific
Most storage materials exhibit phase changes, which cause stresses and, thus, lead to damage of the electrode particles. In this work, a phase-field model for the cathode material NaxFePO4 of Na-ion batteries is studied to understand phase changes and stress evolution. Furthermore, we study the particle size and SOC dependent miscibility gap of the nanoscale insertion materials. Finally, we introduce the nonlocal species concentration theory, and show how the nonlocality influences the results.
Liquid-Vapor Phase-Change Phenomena Springer Science & Business Media
The complex processes of state changes can be interpreted by resorting to Statistical Quantum Mechanics. However, it is well known that a phenomenological description of state changes can be obtained by using the classical continuum theory. This book supplies a panoramic picture of known and new mathematical models which are suitable to describe phase changes from a macroscopic view point. All these models are derived from the theory of continuous systems with a nonmaterial interface and allow to describe processes of solidification, melting, and vaporization. The nonlocal continuum theory of systems with a non material interface provides a more complex mathematical model in dealing with crystal growth either in a pure melt or in a mixture. A chapter is devoted to the analysis of phase changes in ferroelectric and ferromagnetic crystals.
Mechanics of Solids with Phase Changes CRC Press
Detailed understanding of heat transfer and fluid flow is required for many aerospace thermal systems. These systems often include phase change and operate over a range of accelerations or effective gravitational fields.
Continuum Models for Phase Transitions and Twinning in Crystals KIT Scientific Publishing
This work deals with modeling and numerical simulation of fluid flow and heat transfer associated with phase change process inside both isotropic and anisotropic porous media, based on the Two-Phase Mixture Model (TPMM) along with the assumption of Local Thermal Equilibrium (LTE) and Non-Equilibrium (LTNE) conditions. In particular, it demonstrates the necessity and usefulness of a newly proposed smoothing algorithm for handling the sharp discontinuities in the effective diffusion coefficient in order to avoid the occurrence of non-physical “jump” in the predicted temperature distribution during the numerical simulation of the complete phase change process inside porous media. For the purpose of demonstration, one- and two-dimensional phase change problems operated in the Darcy flow regime have been considered.The Finite Volume Method (FVM) has been used on both staggered and non-staggered grid layouts in order to solve the governing conservation equations. In this work, after critically analyzing the drawbacks of the existing enthalpy formulation based on TPMM, a modified formulation has been also developed that can easily accommodate substantial density variations in the single phase regions. The results obtained from the modified enthalpy formulation have been compared with that predicted by the existing modified volumetric enthalpy formulation and excellent agreements have been observed for all tested cases. A thorough parametric study, using both LTE and LTNE models, indicates that the adoption of the proposed smoothing algorithm successfully eliminates “jump” in the predicted temperature distribution and does not alter the overall energy and momentum balance. All tested cases, covering applicable ranges of parametric variations, could be physically interpreted. The methodology is, therefore, recommended for future simulations of complete phase change process inside porous media. The results also show that the modified enthalpy formulation requires significantly less

computation time thanmodified volumetric enthalpy formulation.
Materials Phase Change PDE Control & Estimation World Scientific
This reference book presents mathematical models of melting and solidification processes that are the key to the effective performance of latent heat thermal energy storage systems (LHTES), utilized in a wide range of heat transfer and industrial applications. This topic has spurred a growth in research into LHTES applications in energy conservation and utilization, space station power systems, and thermal protection of electronic equipment in hostile environments. Further, interest in mathematical modeling has increased with the speread of high powered computers used in most industrial and academic settings. In two sections, the book first describes modeling of phase change processes and then describes applications for LHTES. It is aimed at graduate students, researchers, and practicing engineers in heat transfer, materials processing, multiphase systems, energy conservation, metallurgy, microelectronics, and cryosurgery.
Modelling of the Phase Change Kinetics of Cocoa Butter in Chocolate and Application to Confectionary Manufacturing Routledge
This book focuses on latent heat storage, which is one of the most efficient ways of storing thermal energy. Unlike the sensible heat storage method, the latent heat storage method provides much higher storage density with a smaller difference between storing and releasing temperatures. Thermal Energy Storage with Phase Change Materials is structured into four chapters that cover many aspects of thermal energy storage and their practical applications. Chapter 1 reviews selection, performance, and applications of phase change materials. Chapter 2 investigates mathematical analyses of phase change processes. Chapters 3 and 4 present passive and active applications for energy saving, peak load shifting, and price-based control heating using phase change materials. These chapters explore the hot topic of energy saving in an overarching way, and so they are relevant to all courses. This book is an ideal research reference for students at the postgraduate level. It also serves as a useful reference for electrical, mechanical, and chemical engineers and students throughout their work. FEATURES Explains the technical principles of thermal energy storage, including materials and applications in different classifications Provides fundamental calculations of heat transfer with phase change Discusses the benefits and limitations of different types of phase change materials (PCM) in both micro- and macroencapsulations Reviews the mechanisms and applications of available thermal energy storage systems Introduces innovative solutions in hot and cold storage applications
Statistical Mechanics of Phase Transitions Cuvillier Verlag
Efforts have been devoted over the last decades towards modelling phase change kinetics of fats in chocolate. The fats in chocolate have a number of crystal forms and manufacturers must deliver a product with the right polymorph to the consumer. In this work a simplifed mathematical model was developed that clusters six polymorphs into two, namely stable and unstable, depending on their Differential Scanning Calorimetry (DSC) and X-Ray Diffraction (XRD) characteristics. This simplification allowed the phase change kinetics to be estimated from a set of DSC experiments conducted at different cooling and heating rates. The phase change reactions were coupled with the heat transfer equation and used to model temperature profiles and concentration of polymorphs in a model geometry. The model was able to predict both the temperature profiles measured by thermocouples ($\pm 2^\circ$C) and the fat crystals concentration as measured using XRD ($\pm$10%) at various locations in a chocolate slab. The model was applied to the recently developed processes using very high cooling rates such as the FrozenCone process, to explain their capabilities to produce "good" chocolate in spite of the high cooling rates used. Such modelling was not possible with existing models, which usually deal with either heat transfer or isothermal crystallisation kinetics. The main outcomes of this work are (i) the coupling of the reactions kinetics with heat transfer which can be expanded to other processes, (ii) the novel XRD method and (iii) the application to fast cooling processes and their explanation.
Modelling an Organic Phase Change Material (BioPCM) for Buildings Applications Using FEM Springer
Theoretical understanding of heat and mass transfer processes in energy storage and conversion devices is of much interest for a wide variety of engineering applications. Two commonly used mechanisms for energy storage are electrochemical energy storage, such as in Li-ion cells, and phase change based energy storage, such as in phase change materials (PCM).Previous studies show that heat and mass transfer in both PCMs and Li-ion cells are critical processes affecting the performance and safety of these systems. This dissertation investigates several theoretical aspects of heat and mass transfer in these energy storage systems, with the goal of improving performance and safety.In the first part, this dissertation presents a solution for a one-dimensional phase change problem with any arbitrary time-dependent heat flux boundary condition using the perturbation method. The solution presented here is shown to offer key advantages both in accuracy and stability over past papers. The theoretical result is then used for understanding the nature of phase change propagation heat transfer for a wide variety of applications. The model is used to investigate phase change heat transfer including a pre-melted or pre-solidified length between the region of interest and a time-dependent temperature boundary condition. Such a scenario can occur in multiple engineering applications when the heating or cooling process is intermittent in time. Furthermore, the perturbation-based model is used to provide a theoretical understanding of how thermal conductivity and other thermophysical properties affect rate of energy stored (W) and energy storage density (J/m3) as two critical performance parameters of a system. Finally, the method is used to study phase change cooling of Lithium-ion cells.In the second part, this dissertation presents a heat transfer model to determine the core temperature of a Li-ion cell during thermal runaway using surface temperature and chemical kinetics data. The model presented here provides key insight into the internal state of Li-ion cells during thermal runaway. Later, mathematical modeling of species diffusion in Li-ion cell is carried out for improving performance and efficiency of electrochemical energy storage in Li-ion cells.Green's functions approach is used to solve the solution phase and solid-phase diffusion limitations in composite electrodes operating under a time-dependent flux boundary condition. The mathematical models presented in this work are validated by comparison with past studies and numerical simulations. The Green's-function based model is then used to present an analytical Single Particle Model (SPM) based model to predict the terminal voltage and consequently estimate the state of charge (SoC) of Li-ion cells operating under realistic time-dependent current profiles. The mathematical model presented here is compared against numerical simulations and past experimental data for different operating conditions. It is expected that the theoretical models developed in this dissertation will help in designing and improving the performance of electrochemical and phase change energy storage systems.
Solid/liquid Phase Change in Small Passageways Routledge
Continuum Models for Phase Transitions and Twinning in Crystals presents the fundamentals of a remarkably successful approach

to crystal thermomechanics. Developed over the last two decades, it is based on the mathematical theory of nonlinear thermoelasticity, in which a new viewpoint on material symmetry, motivated by molecular theories, plays a central role. This is the first organized presentation of a nonlinear elastic approach to twinning and displacive phase transition in crystalline solids. The authors develop geometry, kinematics, and energy invariance in crystals in strong connection and with the purpose of investigating the actual mechanical aspects of the phenomena, particularly in an elastostatics framework based on the minimization of a thermodynamic potential. Interesting for both mechanics and mathematical analysis, the new theory offers the possibility of investigating the formation of microstructures in materials undergoing martensitic phase transitions, such as shape-memory alloys. Although phenomena such as twinning and phase transitions were once thought to fall outside the range of elastic models, research efforts in these areas have proved quite fruitful. Relevant to a variety of disciplines, including mathematical physics, continuum mechanics, and materials science, Continuum Models for Phase Transitions and Twinning in Crystals is your opportunity to explore these current research methods and topics.