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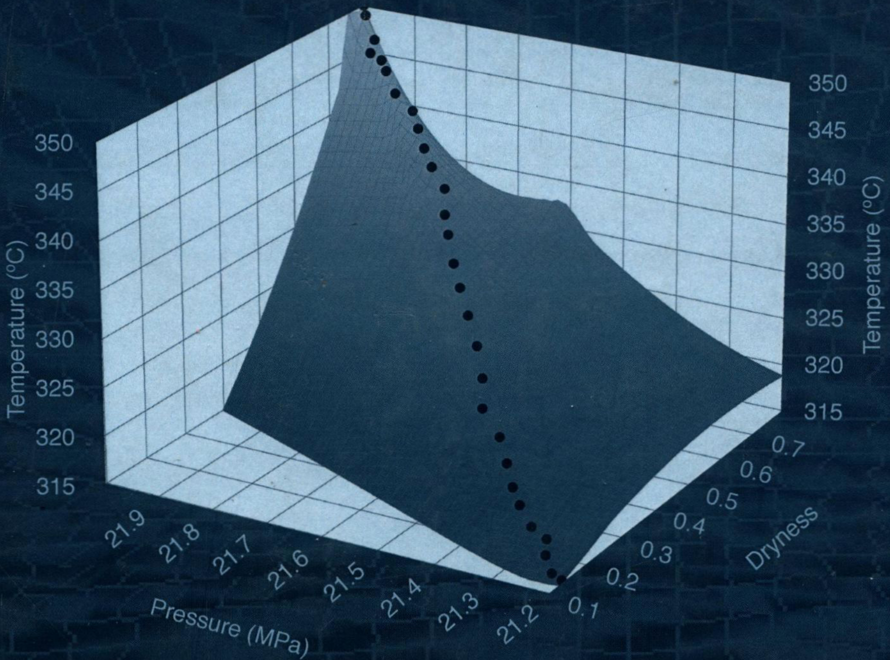

Tubular String Characterization in High Temperature High Pressure Oil and Gas Wells

Jiuping Xu & Zezhong Wu

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Multiphysics Modeling

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Preface

High temperature, high oil pressure, and gas well completion testing have always been technical problem and basic theoretical research is one of the key factors needed to ensure a successful completion test. The completion test basic theory includes: a stress analysis of the completion string, completion string buckling behavior, and temperature and pressure distribution prediction. The completion string is the main bearing and power transmission component for oil and gas well operations and production and it is required to take on a combination of loads, which result in completion string deformation. Because of these complex relationships, completion string stress analysis has become increasingly more complex.

In applied basic theory for deep well testing research, tubular string mechanical analysis is complex as fluid temperature and tubing pressure have a large effect on the force of the tubular string. When well testing, the methods used for determining the temperature and the pressure of the tubular string include: (1) measurements from thermometers and pressure gauges located in the tubing; (2) temperature and pressure measurements at only the well bottom and well head. With these measurements, it is possible to predict the complete distribution using theory analysis technology.

Predicting accurate temperature and pressure profiles in flowing wells can greatly enhance oil and gas production. However, for gas wells with High Temperature High Pressure (HTHP), it is often difficult to operate thermometers and pressure gauges within the tubing itself, and therefore theory analysis can be used as an effective and feasible method.

Over the past decade, the use of numerical simulators with high speed electronic computers has gained wide acceptance throughout the petroleum industry for conducting oil and gas engineering studies. These simulators have been designed for use by engineers who may possess little or no background in the numerical mathematics upon which they are based. Yet in spite of our best efforts to improve these numerical methods to make simulators as reliable, efficient, and automatic as possible, the user of a simulator is constantly faced with a myriad of decisions that have nothing to do with the problem they really want to solve. They need to decide on various numerical questions not germane to the problem at hand. For example, an engineer may need to make a choice between several simulators that use different numerical methods, or may need to choose an iteration method and iteration parameters, a grid spacing, and probably also the time step size. All of these make the process long and complex, adding to production cost and time.

Therefore, with this in mind, we are writing this book for production and testing engineers to provide them with the tools to deal more effectively with the numerical decisions they have to make. To aid in understanding of, and to satisfy curiosity about, the inner workings of the "black box" that is the simulator, we demonstrate the complexities of the oil and gas process by presenting appropriate research studies and developing models the main issues facing the oil and gas exploration industry. Therefore, the first part of the book describes the six conditions in the oil and gas industry. For each condition, the models that are built and algorithms that are designed, implemented and analysed lay the foundation for easy understanding.

But it is not only engineers we had in mind when writing this book. Mathematicians skilled in numerical analysis will, of course, find much of the material already familiar to them. For differential equations and partial differential equation established models, we give proofs for their existence and uniqueness, thus, providing research ideas for mathematicians.

It is our hope that this book will provide food for thought leading to further progress in numerical simulation. All the equations in this book are free from numerical constants (which are dependent on the units being used) and are valid for any consistent set of units. The use of dimension-free equations should become more common as the industry moves to the adoption of the SI (System International) standard of units, as is now being proposed. Accordingly, in the nomenclature following each chapter, we have specified various quantities in the basic SI units of kilograms, metres, and seconds, together with the derived Newton units for force (which equal kg * m/s^2) and the Pascal for pressure (which equals N/mZ). These form a consistent set of units. If the reader prefers, any other consistent set of units can be used, and the equations will still be correct.

Following the oil and gas testing and production process sequence, this book has ten chapters. In the first chapter, a brief background introduction is given for the six conditions: Placing test string, siting, perforating, injection, production, shut-in, and re-opening. In the second chapter, we present the basic theory to be used in the following chapters including the differential geometry, optimization and variational methods. In Chapter 3, HTHP super-deep deviated gas wells are studied which includes a comprehensive consideration of the axial tubular string load, the internal and external fluid pressure, the normal pressure between the tubular and the well wall, the friction and viscous friction of the fluid flow, and the presentation of a new nonlinear differential equations model. In this chapter, also is proved the nonlinear differential equations that are equivalent to a functional extremum problem using a variational method. In Chapter 4, we provide a mechanical analysis of the test string placement. In Chapter 5, we provide a mechanical analysis of setting. When the string is played out from underground, for a string with a packer, the corresponding string deformation needs to be calculated with the packer re-opened. Thus, in Chapter 6, then, we provide a mechanical analysis for the re-opened condition. In Chapter 7, we consider changes to the pressure and temperature with well depth change in HTHP injection wells, and discuss the different heat transfer states from the second interface to the stratum, which contains both steady and unsteady heat transfers. In Chapter 8, we investigate the changes in the pressure and temperature with well depth change in HTHP production wells, and also discuss the changes in the pressure, temperature, density and velocity in the production process. Well control problems have always been difficult, inattention of which could result in serious consequences. In shut-in procedures, ascertaining the downhole status of the gas is essential for effective well control measures, as is knowing the pressure and temperature distribution. In particular, it is very important to determine the maximum wellhead pressure to enable the selection of a proper wellhead assembly to ensure shut-in processes are safe. Thus, in Chapter 9, we also discuss the change in the pressure and temperature with a well depth change in a shut-in condition. In Chapter 10, we discuss software design and development which includes calculation programs and databases. The calculation process completes the basis data input, calculation, and the output of the results. The database selection discuss data input, data saving and delete functions for the tubing and casing.

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Acronyms

AASDT-SITP	Analyzing axial stress and deformation of tubular for steam injection process in HTHP wells based on the varied (T, P) fields
APDTU-VTPF	Analyzing packer's deformation of tubular for unsetting process in HTHP wells based on the varied (T, P) fields
DFA-SIPVF	Dryness fraction analysis for steam injection process of HTHP wells in the varied (T, P) fields
HTHP	High temperature high pressure
NMSOGW-TTBF	Numerical modeling study of oil-gas-water three-phase transient bubbly flow in HTHP wells
NMSQ-DWV	Numerical modelling of steam quality in deviated wells with variable (T, P) fields
OPPV-BCSF	Optimization of perforation parameters for perforated vertical HTHP wells based on comprehensive skin factor
PDPT-IW	Predicting dryness fraction of gas, pressure and temperature in HTHP injection wells
PDPT-SIBUHT	Predicting dryness fraction of gas, pressure and temperature for steam injection based on unsteady heat transmission
PDPTVD-TBF	Predicting on distribution of pressure, temperature, velocity, density of three-phase bubbly flow in HTHP wells
PDTPVD-GLTPTF	Predicting on distribution of temperature, pressure,velocity and density of gas liquid two-phase transient flow in HTHP wells
PPTHVD-STF	Prediction of pressure, temperature, hold-up, velocity and density distribution of steady-state three-phase flow in HTHP wells
PPT-SPDW	Prediction of pressure and temperature in shut-in procedures for HTHP deviated wells
PPTVD-TFSP	Prediction of pressure, temperature, velocity and density of two-phase flow in shut-in procedures for the HTHP gas wells
PTPD-IGWTE	Prediction of temperature and pressure distribution in HTHP injection gas wells considering thermal effect of wellbore
PTP-GW	Predicting temperature and pressure in HTHP gas wells
PTPTF-IWLFM	Pressure and temperature prediction of transient flow in HTHP injection wells by Lax-Friedrichs method
PTPTV-GW	Prediction of temperature, pressure, density, velocity distribution in HTHP gas wells
TSCOGW	Tubular string characterization in HTHP oil and gas wells