



SPE 167263

Decline Curve Analysis for Unconventional Reservoir Systems — Variable Pressure Drop Case

D. W. DeGroot and MacFaughey and T. A. Bastrogans, Texas A&M University

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Abstract

The premise of this work is the development and application of a new methodology to forecast production data in unconventional reservoirs where variable rate and pressure drop data are typically observed throughout production. Decline curve analysis techniques for the estimation of ultimate recovery (EUR) require the constant horizontal pressure conditions during the producing life of the well — whereas it is not regular practice to maintain a constant horizontal pressure profile throughout production in unconventional reservoirs. Therefore, the applicability of the true-rate decline solutions is questionable, and methods to remove pressure variations from rate response are needed for generating future production forecasts.

From a conceptual view point, we propose the utilization of the conventional/equivalent theory along with the recently developed “apparent” true-rate equations, which are formulated by pressure drop data. In order to avoid most complications, a workflow is used where model parameters for the “corrected” decline curve equations are identified using diagnostic “qPM” plots. Horizontal decline curve equations are then convolved with the pressure drop data to achieve a history match and to forecast production.

We provide deterministic application of this technique using an example from an tight pressure high temperature shale gas reservoir. For varying horizontal pressure cases, we show that our proposed technique effectively removes pressure variations from the rate history. We present the differences in computed EUR values using decline curve analysis with and without corrections for varying pressures. In addition, forecasts are generated using supplementary plots such as pressure drop convolved rate versus cumulative production.

Introduction

Decline curve analysis (DCA) is undoubtedly the commonly used technique to estimate ultimate recovery (EUR) of the producing wells in petroleum industry. In simple terms, decline curve analysis is regarded as the extrapolation/forecast of production (only “true-rate” data) rate history. The use of only production data (i.e., true-rate data) to estimate ultimate recovery has been an industry practice since the introduction of the Manual for the Oil and Gas Industry under the Mexican Act of 1918 by the United States Bureau of Mines (1918). Following that publication several authors began to publish their work on decline curve analysis and describe variations. For example, Lamm and Hall (1959) provide initial guidance on the extrapolation of future production of oil wells. Carter (1964) presents a detailed review of the oil industry estimation procedures in 1960s. Johnson and Holtz (1971) introduce the true-rate and the true-rate derivative definitions which lay the basis for the exponential and the hyperbolic true decline solutions. In his seminal work, Arps (1945) presents the derivation of empirical exponential and hyperbolic rate decline relations, which are still the widely utilized solutions for production extrapolations of oil and gas wells. It is noted that Arps’ decline curve relations can be considered as an industry standard and regularly used to forecast production in conventional reservoirs. However, it can also be stated that simplified true-rate (shallow) models such as Arps’ decline curve cannot accurately capture all elements of the performance behavior in unconventional reservoirs. This point will be elaborated later in this section, but we will start proceed with the fundamentals on decline curve analysis.

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Unconventional Hydrocarbon Resources Reza Barati, Mustafa M. Alhubail, 2020-12-03 A comprehensive textbook presenting techniques for the analysis and characterization of shale plays Significant reserves of hydrocarbons cannot be extracted using conventional methods Improvements in techniques such as horizontal drilling and hydraulic fracturing have increased access to unconventional hydrocarbon resources ushering in the shale boom and disrupting the energy sector Unconventional Hydrocarbon Resources Techniques for Reservoir Engineering Analysis covers the geochemistry petrophysics geomechanics and economics of unconventional shale oil plays The text uses a step by step approach to demonstrate industry standard workflows for calculating resource volume and optimizing the extraction process Volume highlights include Methods for rock and fluid characterization of unconventional shale plays A workflow for analyzing wells with stimulated reservoir volume regions An unconventional approach to understanding of fluid flow through porous media A comprehensive summary of discoveries of massive shale resources worldwide Data from Eagle Ford Woodford Wolfcamp and The Bakken shale plays Examples homework assignments projects and access to supplementary online resources Hands on teaching materials for use in petroleum engineering software applications The American Geophysical Union promotes discovery in Earth and space science for the benefit of humanity Its publications disseminate scientific knowledge and provide resources for researchers students and professionals *Well Integrity for Workovers and Recompletions* Les Skinner, 2021-02-25 Well Integrity for Workovers and Completions delivers the concise steps and processes necessary to ensure that production wells minimize failure After understanding the introductory background on well integrity and establishing the best baseline the reference advances into various failure modes that can be expected Rounding out with an explanation and tools concerning economic considerations such as how to increase reserve potential and rate of return the book gives oil and gas engineers and managers a vital solution to keeping their assets safe and effective for the long term gain Helps readers understand how to protect wells through the production workover and recompletion lifecycle both from an economic standpoint and technical view Includes real world examples with quizzes included at the end of each chapter Examines why establishing an integrity baseline is important along with a Well Integrity Management System

Probability, Statistics, and Decision for Civil Engineers Jack R Benjamin, C. Allin Cornell, 2014-07-16 This text covers the development of decision theory and related applications of probability Extensive examples and illustrations cultivate students appreciation for applications including strength of materials soil mechanics construction planning and water resource design Emphasis on fundamentals makes the material accessible to students trained in classical statistics and provides a brief introduction to probability 1970 edition **Design Literacy (continued)** Steven Heller, 1999 This volume also investigates larger movements and phenomena such as Norman Rockwell s lasting impression on Americana issues of

plagiarism and censorship and the Big Idea in advertising and includes profiles of designers whose bodies of work helped determine the look and content of design today BOOK JACKET Humanistic Psychology Joseph Royce,2012-12-06 THE FORMATIVE TENDENCY I have often pointed out that in my work with individuals in therapy and in my experience in encounter groups I have been led to the conviction that human nature is essentially constructive When in a therapeutic climate which can be objectively defined a person becomes sharply aware of more of his or her internal experiencing and of the stimuli and demands from the external world thus acquiring a full range of options the person tends to move in the direction of becoming a socially constructive organism But many are critical of this point of view Why should such a positive direction be observed only in humans Isn't this just pure optimism So quite hesitantly because I have to draw on the work and thinking of others rather than on my own experience I should like to try to set this directional tendency in a much broader context I shall draw on my general reading in the field of science but I should like to mention a special indebtedness to the work of Lancelot Whyte in *The Universe of Experience* Harper and Row 1974 the last book he wrote before his death Though the book has flaws in my judgment this historian has some thought provoking themes to advance I have learned from many others as well **Generation Existential** Ethan Kleinberg,2005 Kleinberg offers new insights into intellectual figures whose influence on modern French philosophy has been enormous including some whose thought remains under explored outside France Derrida Benoît Peeters,2013-08-27 This biography of Jacques Derrida 1930 2004 tells the story of a Jewish boy from Algiers excluded from school at the age of twelve who went on to become the most widely translated French philosopher in the world a vulnerable tormented man who throughout his life continued to see himself as unwelcome in the French university system We are plunged into the different worlds in which Derrida lived and worked pre independence Algeria the microcosm of the *cole Normale Supérieure* the cluster of structuralist thinkers and the turbulent events of 1968 and after We meet the remarkable series of leading writers and philosophers with whom Derrida struck up a friendship Louis Althusser Emmanuel Levinas Jean Genet and Hélène Cixous among others We also witness an equally long series of often brutal polemics fought over crucial issues with thinkers such as Michel Foucault Jacques Lacan John R Searle and Jürgen Habermas as well as several controversies that went far beyond academia the best known of which concerned Heidegger and Paul de Man We follow a series of courageous political commitments in support of Nelson Mandela illegal immigrants and gay marriage And we watch as a concept deconstruction takes wing and exerts an extraordinary influence way beyond the philosophical world on literary studies architecture law theology feminism queer theory and postcolonial studies In writing this compelling and authoritative biography Benoît Peeters talked to over a hundred individuals who knew and worked with Derrida He is also the first person to make use of the huge personal archive built up by Derrida throughout his life and of his extensive correspondence Peeters book gives us a new and deeper understanding of the man who will perhaps be seen as the major philosopher of the second half of the twentieth century *Heidegger* Jacques Derrida,2016-06-16 Few philosophers

held greater fascination for Jacques Derrida than Martin Heidegger and in this book we get an extended look at Derrida's first real encounters with him. Delivered over nine sessions in 1964 and 1965 at the cole Normale Supérieure, these lectures offer a glimpse of the young Derrida first coming to terms with the German philosopher and his magnum opus *Being and Time*. They provide not only crucial insight into the gestation of some of Derrida's primary conceptual concerns, indeed it is here that he first uses with some hesitation the word deconstruction, but an analysis of *Being and Time* that is of extraordinary value to readers of Heidegger or anyone interested in modern philosophy. Derrida performs an almost surgical reading of the notoriously difficult text, marrying pedagogical clarity with patient rigor and acting as a lucid guide through the thickets of Heidegger's prose. At this time in intellectual history, Heidegger was still somewhat unfamiliar to French readers, and *Being and Time* had only been partially translated into French. Here Derrida mostly uses his own translations, giving his own reading of Heidegger that directly challenges the French existential reception initiated earlier by Sartre. He focuses especially on Heidegger's *Destruktion*, which Derrida would translate both into solicitation and deconstruction of the history of ontology and indeed of ontology as such, concentrating on passages that call for a rethinking of the place of history in the question of being and developing a radical account of the place of metaphoricity in Heidegger's thinking. This is a rare window onto Derrida's formative years, and in it we can already see the philosopher we've come to recognize, one characterized by a bravura of exegesis and an inventiveness of thought that are particularly and singularly his.

Heidegger William J. Richardson, 1967. This book, one of the most frequently cited works on Martin Heidegger in any language, belongs on any short list of classic studies of Continental philosophy. William J. Richardson explores the famous *turn* (*Kehre*) in Heidegger's thought after *Being in Time* and demonstrates how this transformation was radical without amounting to a simple contradiction of his earlier views. In a full account of the evolution of Heidegger's work as a whole, Richardson provides a detailed, systematic, and illuminating account of both divergences and fundamental continuities in Heidegger's philosophy, especially in light of recently published works. He demonstrates that the thinking of *Being* for the later Heidegger has exactly the same configuration as the radical phenomenology of the early Heidegger, once he has passed through the turning of his way. Including as a preface the letter that Heidegger wrote to Richardson and a new writer's preface and epilogue, the new edition of this valuable guide will be an essential resource for students and scholars for many years to come.

The Judges of England Edward Foss, 1857. *Care Crosses the River* Hans Blumenberg, 2010. In this accessible collection of short meditations on various topics, Blumenberg works as a detective of ideas, scouring the periphery of intellectual and philosophical history for clues, metaphors, gestures, anecdotes, essential to grasping human finitude. Dan Friedman Dan Friedman, Jeffrey Deitch, Steven Holt, Alessandro Mendini, 1994. Dan Friedman is internationally known as an artist, teacher, graphic designer, and furniture designer. His innovative and arresting work is in many public and private collections, including the Museum of Modern Art and Cooper Hewitt Museum in New York, the Art Institute of Chicago, and

Seibu in Tokyo *Exploring Christian Heritage* C. Douglas Weaver, Rady Roldán-Figueroa, 2024-08 *Cheetahs* Ethan Grucella, 2010-08-01 Introduces cheetahs describing their physical characteristics eating habits life cycle and hunting behavior **Jughead #4** Chip Zdarsky, 2016-02-10 Riverdale High has been taken over by a nefarious outside force Or has it It s up to Jughead and Dilton to get proof but can the mysterious Captain Slackbeard show the way It s adventure on the high seas and in the classroom for the gang Yar Three Tragedies Federico García Lorca, 1955 Here in the authorized translation by James Graham Luj n and Richard L O Connell with an illuminating biographical introduction by the poet s brother Francisco Garc a Lorca are three tragic dramas by the great modern Spanish poet and playwright which have caught the imagination and won the critical acclaim of the literate world **Batman: Detective Comics Vol. 3: Emperor Penguin** John Layman, 2013-11-26 Oswald Cobblepot has a plan No longer content with merely being the crime lord the Penguin he yearns for the love of Gotham City All he has to do is call a hit on Bruce Wayne and in one night the Penguin goes from notorious criminal to beloved savior of Gotham Everything is going exactly according to plan But when chaos strikes even the best plan crumbles And when Joker returns to Gotham chaos comes with him Now with Penguin temporarily out of commission and Batman busy trying to stop Poison Ivy and a group of Joker obsessed maniacs a new threat creeps in from the sidelines He calls himself Emperor Penguin He s everything Penguin was and more And he s bad news for Batman and very bad news for Oswald Cobblepot BATMAN DETECTIVE COMICS EMPEROR PENGUIN Acclaimed writer John Layman CHEW makes his mark on the Dark Knight Detective with incredible art from Jason Fabok BATMAN THE DARK KNIGHT and Andy Clarke BATMAN AND ROBIN Collects issues 13 18 **The Last Flower** James Thurber, 1998

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