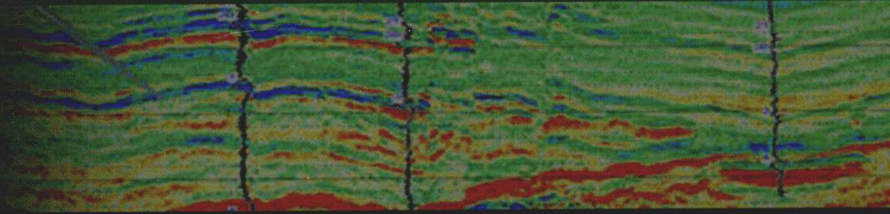

Streamline Numerical Well Test Interpretation Theory and Method

Yao Jun Wu Minglu

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FOREWORD

This work, *Streamline Numerical Well Test Interpretation Theory and Method*, written by Professor Yao Jun, is based on the summary and abstraction of scientific achievements and application experiences after years of data accumulation in the numerical well test field. It gives expression to new trends in theories and methods in this field with distinct originality and practicability, provides an effective method for the application of well testing data in reservoir fine description, especially the determination of residual oil distribution. Also, the way in which the theories are systematically described and the integrity of this book provide a factual basis for readers to understand streamline numerical well test interpretation theory and method in detail.

In this book, the following principles are outlined, in terms of theories and methods:

(1) Strong innovations. The streamline method is used in numerical well test interpretation for the first time, which breaks the traditional idea that one well test equation should be built for one testing well. Based on a truè reservoir model and taking into consideration the influence of production history, oil layer heterogeneity, multi-phase fluid and non-uniform distribution, multi-well interference, layer cross-flow and complex reservoir boundaries, the streamline numerical well test interpretation model is built including a mathematical model of production and testing periods. The mathematical model of the production period is used to simulate production history, and the streamline method is used to quickly calculate the distribution of pressure, saturation and streamlining; the mathematical model of the testing period is built by flow equations of each streamline surrounding testing well, which is used to simulate bottom hole pressure change of testing period, to obtain theoretical pressure response of the testing well and to provide a detailed description of formation and flow.

(2) Strong systematicity. Streamline numerical well test interpretation theory and method systems are formed with all kinds of numerical well test interpretation models from single-layer reservoir models to multi-layer reservoir models: the water-flooding reservoir model to the chemical-flooding (polymer flooding, alkaline flooding, alkaline/polymer binary combination flooding) model; the sandstone reservoir model to the carbonate dual porosity media reservoir model; the fully perforated well model to the partially perforated well model; the regularly damaged well model to the irregularly damaged well model; the vertical testing well model to the horizontal testing well model.

(3) Strong practicability. The streamline numerical well test interpretation method avoids the disadvantages of conventional well test and numerical well test interpretation methods; this well test interpretation model considers the influence of complex factors including development and geology, which coincides better with real reservoirs than other models. With powerful analysis capabilities and reliable results, this method can not only provide conventional well test parameter information, but can also provide the dynamic parameter distribution of residual oil and polymer concentrations. In addition, the streamline method and the multi-population genetic algorithm greatly improve the speed of well test interpretation and application scale with strong field practicability. The streamline numerical well test theory and method introduced in this book has been programed to streamline numerical well test interpretation software with complete functionality, reliable practicability and independent intellectual property rights, which is also widely used in Shengli, Zhongyuan, Nanyang and Dagang Oilfields and provides a considerable economic benefit.

With a series of pictures, and with full and accurate data, this book not only has a high academic value, but also has a broad application, and can serve as a reading and reference book for scientists, engineers and college students in petroleum and other relevant fields.

Academician of the Chinese Academy of Science
Guo Shangping

INTRODUCTION

Correct evaluation of dynamic parameters in the developed reservoir, especially residual oil distribution, is the basis for establishing stimulation measures or enhanced oil recovery (EOR) schemes scientifically and reasonably. Also, determination of storage parameters and residual oil distribution with well testing data is a convenient, economical, reliable and practical method.

The conventional and modern well test interpretation method, which is based on a reservoir conceptual model and analytical solutions, is a relatively practical method in oil field exploration and during the early development period. However, most oil fields at home and abroad enter the middle-and later-development periods, and reservoir flow environment becomes increasingly complex (e.g., formation heterogeneity, fluid non-uniform distribution, multi-well interference and cross-flow between layers). This situation is totally different with the ideal models of conventional and modern well testing. In this case, conventional well test and modern well test interpretation methods could not satisfy the needs of oil field development and evaluation.

In order to meet the demands of testing data interpretation in middle and later periods, the numerical well test interpretation method was proposed in the 1990s. This method is based on a true reservoir model, builds the well test interpretation model by considering complex boundaries, production history, multi-phase flow, heterogeneity well pattern and well type, solves with numerical methods and interprets with automatic matching methods for multi-parameter well testing. In order to distinguish it from the well test interpretation method based on analytical solutions, this method is called the "numerical well test interpretation method". At present, the main solution methods for the numerical well test interpretation model include finite difference, finite element, boundary element and Green element methods, which are all based on 2-D or 3-D grid generation to realize pressure dynamic fine simulation of the testing well by well grid refinement; the speed of calculation and the accuracy do not easily satisfy the needs of numerical well test interpretation. Hence, the use of present numerical well test interpretation methods is poor and it can not be widly applied.

For the problem of slow speed and small application scale during the numerical well test interpretation method with finite difference algorithm, the streamline method is introduced into well test interpretation and the streamline numerical well test interpretation method is proposed. The mathematical model adopted in this method is divided into production and testing periods. The mathematical model of the production period is used to simulate production history, and the streamline method is introduced for fast calculation of pressure distribution, saturation distribution and concentration distribution (chemical flooding), which are taken as the initial condition of the testing well in the testing period. Meanwhile, the mathematical model of the testing period is used to simulate bottom-hole pressure change of the testing well in the testing period, and it is made by the flow equations of each streamline surrounding testing well, then a simultaneous solution is used to obtain theoretical pressure response. The models in the two periods are the true reservoir model, which can consider the influence of complex factors, such as production history, oil layer heterogeneity, multi-phase fluid and non-uniform distribution, multi-well interference, cross-flow between layers and complex reservoir boundary; furthermore, the introduction of the streamline method guarantees the calculation speed and accuracy. By changing the parameters of the well test interpretation model constantly and by automatic matching of theoretical pressure response and testing pressure data of the testing well in the well test interpretation model, accurate well test interpretation parameters can be obtained.

This method has formed a consummate well test theoretical system and interpretation method from single-layer reservoirs to multi-layer reservoirs, sandstone reservoirs to fractured dual-porosity media reservoirs, water flooding reservoirs to polymer, alkaline and chemical combination flooding reservoirs, which greatly enriches numerical well test interpretation methods. Meanwhile, streamline numerical well test interpretation software, with independent intellectual property rights, has been programed which is widely applied in Shengli, Zhongyuan, Henan and Dagang oil fields, and a practical method to determine the distribution of permeability and residual oil has been established based on well test data.

This book presents the research achievements in this field in the last 10 years in 12 chapters. Chapter 1 describes the development history of well test theory, analyzes the limitations of modern well test interpretation methods, and then proposes the concept and framework of numerical well testing. Chapter 2 introduces basic principles and solution procedures of streamline numerical simulation theory and method, which will help readers who have not previously used the streamline numerical simulation method. Chapters 3-9 study streamline numerical well test interpretation models in many kinds of reservoirs and wells systematically: from single-layer reservoirs to multi-layer reservoirs; single-layer sandstone water flooding reservoirs to multi-layer sandstone water flooding reservoirs; multi-layer sandstone water flooding reservoirs to multi-layer sandstone chemical flooding models and the model considering components; single-porosity media reservoir to dual-porosity media reservoir; normal inner boundary conditions with a totally perforated oil layer to complex near well boundary conditions with a partially perforated oil layer considering perforation location and irregular damage; conventional well (straight well) to complex structural well (horizontal well). In particular, the numerical well test interpretation method is firstly introduced to chemical flooding and dual porosity media reservoirs, which enriches and develops numerical well test interpretation methods and builds a better methodology system. Chapter 10 presents a multi-parameter streamline numerical well test automatic match interpretation method based on a double-population genetic algorithm, which lays the foundation to fast automatic match of numerical well testing. Chapter 11 introduces streamline numerical well test interpretation software, with independent intellectual property rights, which is programed based on the above theoretical studies. Chapter 12 describes the application study of streamline numerical well test software, and the programed software is applied in actual fields with many different types of reservoir. The biggest application scale could consider 177 wells (121 production wells, 56 injection wells) working at the same time, while the longest simulation history is 35 years and the most simulation layers is 5 layers. Also application reservoir types refer to water flooding reservoirs, polymer flooding reservoirs and alkaline-polymer combination flooding reservoirs. The interpretation results include not only conventional well test interpretation parameters (well bore storage coefficient, skin factor etc.), but also permeability distribution of whole reservoirs, residual oil distribution, chemical concentration distribution (chemical flooding) and displacement front position, etc.

CONTENTS

CHAPTER 1

Numerical Well Testing Interpretation Theory and Method

1.1 WELL TESTING OVERVIEW

In order to obtain maximum development benefits, a practical reservoir model which conforms to real reservoir conditions needs to be built. Using reservoir modes and reservoir engineering methods, varied oil and gas field development plans and operation modes can be simulated to predict precisely the dynamic characteristics of the reservoir and wells; thus scientific and suitable development decisions can be made. Building a reservoir model needs geological data, geophysical data, logging data, core analysis data and production performance data, all of which can be obtained by direct measurement such as core and reservoir fluid sampling and data interpretation such as analysis of seismic data, logging data, well testing data and pressure, volume temperature (PVT)data. Seismic data, logging data and core analysis data can only provide a static description of the reservoir, while well testing data, serving as the main foundation of reservoir model building, can supply dynamic information about reservoirs and wells.

Through well test analysis, we can obtain various dynamic data of reservoirs and wells, such as effective permeability (formation capacity, flow coefficient), initial or average reservoir pressure, damage or improvement conditions for near the well bore area, producing reserves, fault and boundary conditions, inter-well communication situations, and so on.

At present, well test technology is widely used in oil and gas fields and has become one of the principle technologies employed during oil and gas field exploration and development. Nowadays many waterflood oil fields have entered the late development period, and current well test theory and interpretation methods can not satisfy the actual production requirements. The existing problems in well testing are discussed below by reviewing and analyzing the well test development history and the present situation.

1.2 DEVELOPMENT HISTORY OF WELL TESTING THEORY

Well testing is an important part of oil and gas reservoir monitoring, which refers to various areas including reservoir geology, reservoir physics, formation and fluid properties, flow theory, optimization theory, computer technology, testing techniques, measuring instruments, and so on. Well testing theory has developed following the development of testing instruments.

1.2.1 Development History of Testing Instruments

More than half a century ago, we could only use the recording pen to record the maximum bottom-hole pressure using a simple glass tube manometer. After many years of development, the design and manufacture of manometers have become very sophisticated and greatly improved. Mechanical manometers comprising three key components which include recording systems, travel-time systems and pressure sense systems, can record various characteristics of bottom-hole pressure changes. The manometers can work for 360—480 h down hole and endure temperatures of between 150 and 370℃. The accuracy achieved can be to within 0.2% and there are dozens of varieties.

Over the past 40 years, computer technology has developed rapidly and has been used to advance the field of well testing. In the late 1960s, Hewlett-Packard Company successfully developed the first quartz electronic manometer with an accuracy of within 0.025%. Its degree of sensitivity is up to 0.00014 MPa and the scan rate can reach one measuring point per second. Quartz electronic manometers can be controlled remotely, bottom-hole pressure change can be observed through a secondary instrument and the length of measuring time can be adjusted according to requirements, thus it can greatly improve the quality of the well test data and the effectiveness of data analysis. Currently there are dozens of kinds of electronic manometers; some can directly read bottom-hole pressure and temperature while others can store the recorded data underground and then the data can be played back when the instrument is retrieved. The quartz electronic manometer is currently one of the most precise and sensitive types of manometers. The emergence of electronic manometers, with high accuracy further promotes the development of well test theory, enhances the reliability of well test interpretation results and enlarges the application area of well test technology.

1.2.2 Development History of Well Testing Theory and Interpretation Methods

The development history of well test theory and interpretation methods can be divided into two stages, as described below.

1.2.2.1 Conventional Well Testing Analysis Methods Before the 1970s

Before the 1940s, our knowledge was confined to static pressure because the manometers could only measure the reservoir static pressure. Later, it was found that the measurement of static pressure was related to time, and the length of pressure build-up reflected the formation permeability around the well bore.

In 1933, Moore et al. published a paper which proposed a method to determine formation permeability using dynamic pressure data. Then two papers published in 1950 laid the foundation for well test theory. One was published by Horner(1950), who proposed using a diagram method to interpret pressure test data, i.e. he proposed that there is a linear relationship between the pressure build-up value and the logarithm value of Horner time (Horner Method). The other paper, written by Miller et al.(1950), proposed the linear relationship between pressure build-up value and shut-in time (MDH Method). Both of these two methods are used currently. Generally speaking, the Horner method is applicable to new wells in oil fields which are not fully developed, while the MDH method fits wells in oil fields which have been developed for a period of time. These two methods are the representatives of conventional well test interpretation methods. The so-called conventional well test interpretation methods refer to the methods represented by the Horner method which use the slope and intercept of the straight line to reversely solve the formation parameters. In addition, conventional well test interpretation methods also include the MBH method, the Y-function method, and so on.

Conventional well test methods mainly focus on the interpretation of the test data of isotropic and homogeneous reservoirs with comparatively mature theories, simple principles and convenient applications. However, conventional well test interpretation methods also present several drawbacks.

(1) Conventional well test interpretation methods mainly focus on the interpretation of mid-to late-period pressure data, which needs a long period of well test time, thereby affecting oil production. Furthermore, it is rather difficult to get mid-to late- period well test data for reservoirs with very low permeability.

(2) While using the conventional well test interpretation methods, the selection of the straight-line section will affect the subsequent interpretation of

results. This artificial selection will inevitably produce some error.

(3) Conventional well test interpretation methods do not make a detailed analysis of early period data, so they can not precisely evaluate the well bore storage capacity.

(4) The limited date obtained during analysis with conventional interpretation methods brings some difficulties in recognition of reservoir model. Sometimes one single curve shape reflects characteristics of different reservoir models.

1.2.2.2 Modern Well Testing Analysis Methods After the 1970s

The modern well test interpretation methods developed since the late 1960s solve the above problems to some extent. The fundamental principle of these methods is to rebuild the mathematical model with various boundary conditions based on the original reservoir model, then to solve the mathematical model by analytical or semi-analytical methods and draw well test interpretation charts for analysis. For instance, Ramey(1970) delivered a type-curve chart of a well with well bore storage effects and skin effects in an infinite homogeneous reservoir. Then Gringarten and Ramey(1973) adjusted this chart to make it more applicable and to reduce the ambiguity of interpretation. In 1974, Gringarten et al. published a paper which delivered type-curves for wells with vertical fractures. In 1980, Bourdet et al.(1980) presented type-curves of dual porosity reservoirs and the corresponding pressure derivative curves, which made the model and flow regime diagnosis more precise. The introduction of systematic analysis methods further developed the well test interpretation method, which evolved from type-curves matching to various automatic matching methods such as nonlinear regression, neural networks, control theory and so on. Based on these theories and with the assistance of computers, a large amount of practical well test interpretation programs were designed and widely used in oil and gas fields.

Modern well test interpretation methods have the following characteristics:

(1) The application of systematic analysis concept and numerical simulation method further developed the well test interpretation theory .

(2) With consideration for the impact of well bore storage effects and skin factors on pressure response, modern well test interpretation methods can analyze the early data and obtain more valuable information from it, which could not be utilized in the past.

(3) It improved the conventional well test interpretation methods by giving the approximate beginning time of the semi-log straight line, which enhanced the reliability of semi-log curve analysis.

(4) Through the matching of actual pressure data and dimensionless pressure-dimensionless time curves in theoretical charts, reservoir parameters can be quantitatively analyzed partially or generally and some parameters which could not be calculated using conventional well test interpretation methods now can be obtained.

(5) Different reservoir models can be recognized using pressure derivative curves, which provide the basis for intended analysis and enhance the accuracy of the analysis.

(6) The entire interpretation process is interpreting-while-verifying. The recognition of each flow stage and the computation of each parameter can almost be obtained from two different sources and then be compared.

(7) The final interpretation of results can be verified and matched using numerical simulation, which enhances the reliability and accuracy of the interpretation of results.

1.3 LIMITATIONS OF MODERN WELL TESTING INTERPRETATION METHODS

Since the 1970s, well test theory and interpretation methods have not made any big progress in essence, which means that well test theory and interpretation methods can not meet the requirements of oil and gas fields' fast development. The commonly used Gringarten type-curve diagram well test interpretation method is used as an example below to illustrate the limitations of modern well testing interpretation methods.

1.3.1 Well Testing Interpretation Model of Homogeneous Reservoir

The Gringarten type-curve chart is currently a widely used modern well test interpretation chart which is delivered by solving well test interpretation models of homogeneous reservoirs with the following assumptions.

(1) The reservoir is composed of infinite, homogeneous and isotropic single oil layer (i.e. the permeability, porosity, thickness and fluid properties are all uniformly distributed). The testing well is located in the reservoir center.

(2) Single-phase flow underground with constant production rate.

(3) Fluid is slightly compressible and the compressibility is a constant.

(4) The well produces at a constant rate and the formation pressure is uniformly distributed before production.

(5) The model neglects gravity and capillary pressure effects.

Based on the above assumptions, the physical model is shown in Figure 1.1.

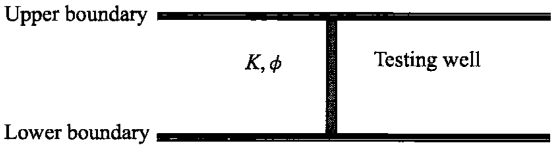

FIGURE 1.1 Schematic map of homogeneous reservoir model with a single well

The well testing interpretation model is

$$\begin{cases} \dfrac{\partial^2 p_D}{\partial r_D^2} + \dfrac{1}{r_D}\dfrac{\partial p_D}{\partial r_D} = \dfrac{\partial p_D}{\partial t_D} \\ p_D(r_d, t_D)\Big|_{t_D=0} = 0 \\ C_D \dfrac{dp_{WD}}{dt_D} - \left(\dfrac{\partial p_D}{\partial r_D}\right)_{r_D=1} = 1 \\ p_{WD} = \left[p_D - s\left(\dfrac{\partial p_D}{\partial r_D}\right)\right]_{r_D=1} \\ \lim\limits_{r_D \to \infty} p_D(r_D, t_D) = 0 \end{cases}$$

where, subscript D represents dimensionless. p_D is dimensionless pressure; r_D is dimensionless radius; t_D is dimensionless time; C_D is dimensionless well bore storage factor; p_{WD} is dimensionless bottom-hole flow pressure; S is skin factor.

The mathematical model above can be solved using an analytic method (through analytical conversion of the Laplace domain solution), a semi-analytic method (through numerical conversion of the Laplace domain solution), and a numerical solution (through the finite difference method). Then, by the combination of these parameters, we can obtain the dimensionless pressure and derivative type-curve chart (as shown in Figure 1.2).

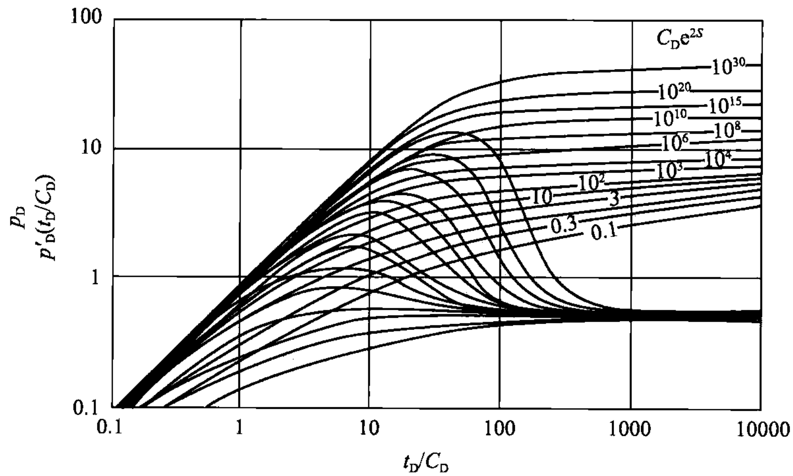

FIGURE 1.2 Modern well test interpretation type curves of a homogeneous reservoir

1.3.2 Limitations of Well Testing Interpretation Models

From the model assumptions we know that the well test interpretation above is based on a comparatively ideal reservoir model (as shown in Fig1.3). It is very different from the real reservoir model because it does not consider many geological and developmental factors which can affect the pressure response of the testing well, including:

(1) Reservoir heterogeneity. In the horizontal direction, it includes the heterogeneous distribution of reservoir rock properties such as permeability, porosity and thickness and fluid properties such as fluid density, oil/gas/water saturation and compressibility. In the vertical direction, the reservoir is composed of several layers and each layer's lithology and fluid properties are different because of the sedimentary effect. These heterogeneities result in the existence of residual oil and low oil field recovery. However, the well test interpretation model above does not consider these factors.

(2) Impact of multi-well production on well test. In real reservoir conditions, production wells or injection wells may exist around the testing well and these wells can dramatically affect the fluid distribution. If these wells around the testing well do not stop production or injection during the testing, they will certainly affect the testing well. In addition, even if these wells are shut in, the irregular oil/water boundary formed around the testing well will also affect the pressure response of the testing well and this effect can not be substituted by simple linear boundary or fault.

(3) Multi-phase flow effect. Currently, common well test interpretation software all use the Perrine-Martin equation to simplify multi-phase flow testing. This method only adjusts the parameters such as compressibility coefficient and fluid mobility and its flow equation form is identical to that of single-phase flow. Furthermore, underground multi-phase fluids can cause saturation distribution and phase change such as condensation and miscible phase, and then cause the corresponding change in fluid properties underground such as density and compressibility factor, which will definitely affect the pressure response of the testing well.

(4) Impact of production history. At present, commonly used well test interpretation models all make the assumption that the reservoir pressure and fluid saturation are all uniformly distributed before the well test. Actually, production or injection history will cause redistribution of underground fluids and pressure, and this non-uniform distribution before well test will definitely affect the pressure response of the testing well.

Due to the big difference between the real reservoir model and the ideal reservoir concept model on which the well test interpretation base, the well test interpretation theory and methods are apparently deficient and their field applications are seriously restricted. It can be said that present well test theory and interpretation methods to some extent can not satisfy the requirements of oil field production tail and the development of some special oil fields.

With the development of oil/gas exploration and development techniques, more and more types of reservoirs which also include some tough-to-tap reservoirs, are put into production. According to the underground fluid properties, these reservoirs can be classified as heavy oil reservoirs, black oil reservoirs, volatile reservoirs, condensate gas reservoirs, gas reservoirs, and so on. On the basis of permeability, reservoirs can be classified as low-permeability reservoirs and high-permeability reservoirs. In terms of development mechanisms, there are elastic developments, water flooding developments, gas injection developments (miscible or immiscible), chemical flooding developments and so on. Each kind of reservoir has its own special development methods and unique underground flow mechanism. So the corresponding well test theory and interpretation methods for these reservoirs are much more complicated. Reservoir type, properties and drive mechanism must be taken into consideration when computing the pressure response.

Although interpretation software makes some adjustments for the inner and outer boundary and variant production rate of the model, the well test interpretation model is not changed in essence. Consequently, much field information, especially the test data of production tail, are hard to match. Some test curves are well matched because man-made boundaries or faults are added, but actually there is not boundary and it is caused by the oil/water distribution. The differences between the shapes of some real test curves and type-curves is entirely a reflection of the complexity of underground reservoir. This ideal and simplified reservoir concept model can not represent the underground reality. As a result, currently used over-ideal well test theory apparently can not satisfy the practical requirements of oil and gas field development.

1.3.3 Cause Analysis

There are many causes of the limitations listed above. Firstly, due to the restricted ability to solve the mathematical model, it is hard to develop so-called well test interpretation type-curve charts and interpret the real test data if the actual flow model is not simplified. Secondly, in the past few decades, well-known experts in the field of well testing almost all focus on the well test itself and do not pay enough attention to the combination with reservoir geology and reservoir engineering methods. In fact, well test theory and interpretation methods refer to many scientific domains and interdisciplinary combination is needed to promote the development of this subject. With the combination of reservoir engineering and well test interpretation methods, we examine the essence of well testing from different perspectives, which will be very beneficial to the further development of well test theory and interpretation methods.

1.4 ESSENCE OF WELL TESTING INTERPRETATION

1.4.1 Perspective from Systematic Analysis

Any study object can be seen as a System (S). If a stimulation or called Input (I) is imposed on the system, it will give a corresponding reflection called Output (O), as Figure 1.3 shows.

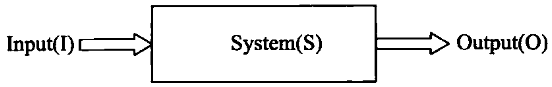

FIGURE 1.3 Schematic diagram of systematic analysis

There are two categories of problems in systematic analysis. One is where the system structure and input signal I are known, unknown output O is to be solved. This type of problem is called Direct Problem, indicated by

$$I \times S \to O$$

The other is where the system S is unknown while input I and output O of the system are known, the structure or characteristic of the system S is to be solved reversely, indicated by

$$O/I \to S$$

If the reservoir and the testing well are seen as one system, an input signal I is imposed on S during the test, i.e. the testing well is opened and produces (or injects) at a constant rate or is shut in, then it will cause the pressure change in the system S, which is the output signal O of S and can be measured by test instruments, as Figure 1.4 shows.

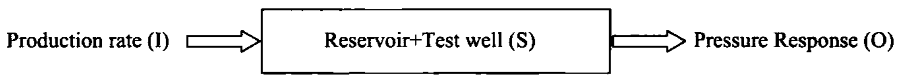

FIGURE 1.4 Schematic diagram of well test

Well testing is the process of measuring the changes of production or injection rate and the bottom-hole pressure of the testing well, i.e. obtaining input or output signals of the system. While the purpose of well test interpretation is to recognize the system S, namely determining the type and characteristic parameters of the reservoir by using these data including input I (production rate) and output O (pressure change) with the combination of actual initial and boundary conditions of the reservoir and other relevant information of the reservoir and wells. That is to say the process of well test interpretation is a typical inverse problem.

There are many methods to solve an inverse problem.To make it convenient for field use, well test researchers developed well test interpretation type-curves and the mission of well test interpretation can be finished by matching the real test curves with type-curves to determine the characteristic parameters of the reservoir and testing well. Some researchers proposed automatic matching methods and ascribed the well test interpretation to an optimization problem, which can be described as follows:

$$v_{\min} = \sum_{i=1}^{N} \left(p_{\text{model}i} - p_{\text{real}i} \right)^2$$

$$v_{\min} = \sum_{i=1}^{N} \left| p_{\text{model}i} - p_{\text{real}i} \right|$$

There are also many methods to solve this type of problem, such as the optimization method, the neural network method, the cybernetics method, the currently used generalized pulse spectrum technique and perturbation method, and so on.

The introduction of systematic analysis methods into well test interpretation is great progress which makes well test interpretation results more sophisticated and suitable to reality.

1.4.2 Perspective from Reservoir Model Building

The purpose of well test interpretation is to determine reservoir type and its characteristic parameters which can compose a simplified reservoir model. Whether this reservoir model fits the practical condition or not is determined by whether or not the simplification of the well test interpretation model is reasonable.

Well test interpretation is an adjustment or verification process of the reservoir model and this concept is critical to the development of well test theory. Starting from this concept, we can deepen our understanding of well testing and enlarge the application range of well testing in oil and gas field development. Apparently, if the well test interpretation model is over-simplified, the reservoir geological model obtained will also be over-simplified.

The present well test interpretation model is a single-phase, single-well, single-layer and homogeneous (including rock properties, fluid properties and fluid distribution) simplified model, so the reservoir model determined by these well test theories and interpretation methods is certainly a single-phase, single-well, single-layer and homogeneous simplified model and the parameters determined by well test interpretation can only reflect the average properties of the reservoir which are of little value to the fine dynamic performance evaluation in oil field production tail. Clearly, this over-simplified model can not reflect the actual complex reservoir model very well. From this perspective, the well test interpretation model is very important and must be identical to the real condition. Only by satisfying this requirement can we determine the parameters of reservoirs and testing wells exactly.

Whether we can get finer and more microscopic (not average) geological characteristics from well test interpretation is completely determined by whether or not the well test interpretation model has considered these factors. Currently proposed methods using single-well test interpretation models to determine the distribution of residual oil saturation are completely unnecessary because the well test interpretation model does not take the factors which affect the distribution of residual oil into consideration.

From the perspective of reservoir model building, the well test interpretation model must be much closer to the real reservoir geological model and has to consider the following geological and developmental factors:

(1) Reservoir heterogeneities in horizontal or vertical directions.

(2) Impact of multi-well production on the testing well.

(3) Effect of multi-phase fluid distribution and their phase changes.

(4) Impact of production history on the pressure response of the testing well.

That is to say, the constructed well test interpretation model must be the real reservoir