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A study of pressure transients in naturally fractured reservoirs

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Abstract

In naturally fractured reservoirs, pressure transient experiments frequently show non-uniform responses. In order to appropriately characterise reservoir parameters, many methodologies can be utilised to examine pressure behaviour in dual porosity reservoirs. Traditional semi-log analysis, type curve matching (using commercial software), and Tiab's Direct Synthesis (TDS) techniques were used to analyse pressure transient testing in naturally fractured reservoirs in this paper. In the event of a naturally fractured formation with a vertical hydraulic fracture, the TDS approach was also used. Under pseudo steady state matrix flow, these techniques were applied to a single layer naturally cracked reservoir. Various reservoir characteristics, such as permeability and skin, can be derived by observing the distinct characteristics of the different flow regimes that appear on the pressure and pressure derivative curves in skin factor, and fracture properties. A comparison of the findings of semi-log analysis, software matching, and the TDS method for naturally fractured reservoirs is presented. In the case of wellbore storage, the early time flow regime can be masked, resulting in a semi-log analysis that is incomplete. Furthermore, because all of the flow regimes must be observed, type curve matching frequently results in a non-uniqueness solution. The direct synthesis approach, on the other hand, used an analytical equation to calculate reservoir and well parameters without having to match type curves. The pressure behaviour of wells crossed by a uniform flux and infinite conductivity fracture is investigated using the TDS technique for naturally fractured reservoirs with a vertical fracture. The fracture half-length, as well as other reservoir properties, was calculated using the different flow regimes on the pressure derivative curve. When compared to semi-log analysis and type curve matching, the findings of several scenarios revealed that the TDS technique has significant advantages. Even if particular flow regimes are not observed, it can be employed. When compared to the available core data and software matching results, direct synthesis results are accurate.

Introduction

The analysis of pressure data received during a well test in dual porosity formation has been widely used for reservoir characterization. Conventional semi-log analysis and log-log type curve methods are the early techniques used to analyse pressure transient data. However, both methods need certain criteria to give accurate results, such as; all flow regimes must be identified in the pressure and pressure derivative plot. In case some flow regimes are not identified, type curve matching will give a non-uniqueness solution and is essential trial and error, and semi-log analysis cannot be completed. Tiab used a new method to analyse pressure transient tests, called “Direct Synthesis Technique”. This method can calculate different reservoir parameters without type curve matching by using pressure and pressure derivative log log plots. In 1994, Tiab extended the work to vertically fractured wells in closed system. Engler and Tiab developed direct synthesis method to analyse pressure transient tests in dual porosity formation without using type curve matching. They used analytical and empirical correlations to calculate the naturally fractured reservoir parameters. Jalal discussed the analytical solutions of wells in dual porosity reservoirs with a vertical fracture. The direct synthesis method offers many advantages in analysing pressure transient tests.

The objective of this paper is to analyse pressure transient in naturally fractured reservoirs using: conventional semi-log analysis, type curve matching (using commercial software), and Tiab’s direct synthesis method to correctly characterize the reservoir properties. These techniques were applied to naturally fractured reservoirs, with and without hydraulic (vertical) fracture. Direct synthesis method uses a log-log plot of pressure and pressure derivative data versus time to calculate various reservoirs and well parameters. It uses the pressure derivative technique to identify reservoir heterogeneities. In this method, the values of the slopes, intersection points, and beginning and ending times of various straight lines from the log-log plot can be used in exact analytical equations to calculate different parameters.

Naturally fractured reservoirs with a vertical fracture

The pressure behaviour of a dual porosity formation intersected by uniform flux and infinite conductivity fracture can be investigated using log–log plots of pressure and pressure derivative functions. The direct synthesis technique can be used to calculate reservoir parameters such as skin, wellbore storage, permeability, interporosity flow parameter, relative storability and half-fracture length without type curve matching. The applied assumptions are: the reservoir is isotropic, horizontal, and has constant thickness and fracture permeability. The fractured well is producing at constant rate with constant viscosity, slightly compressible fluid. In addition, the fracture fully penetrates the vertical extent of the formation and has the same length in both sides of the well. A pseudo steady state interporosity flow between the matrix and the fracture system is also assumed.

Infinite Conductivity Fracture

The pressure and pressure derivative obtained for infinite conductivity fracture are the same as the uniform flux fracture except for a fourth dominated flow regime called bi-radial flow. This flow regime can be identified by a straight line of slope 0.36. It corresponds to the transition period between the early time linear flow regime and the infinite acting radial flow regime. The characteristics of the linear, radial, and pseudo steady state flow periods are the same as illustrated earlier in the case of uniform flux fracture.

Conclusions

The use of pressure derivative plots improved the analysis of well test data. Different flow regimes can be identified on the derivative log-log plots. Type curve matching can give good results in case all of the flow regimes are identified. In this study, Tiab direct synthesis technique was shown to be accurate and simple. It gave direct estimates of reservoir parameters and fracture characteristics by using a log-log plot of pressure and pressure derivative data without type curve matching. In case of high wellbore storage, the conventional semi-log analysis gives inaccurate results and cannot estimate all naturally fractured reservoir parameters. When not all the flow regimes are identified, type curve matching gives non-unique solution. However, the direct synthesis technique gives accurate results of the naturally fractured reservoir parameters and fracture properties. The direct synthesis method, showed accurate results compared to commercial software matching. It can be used to calculate the reservoir and fracture properties in case of a well crossed by a uniform flux or infinite conductivity fracture. In case of naturally fractured reservoirs with a vertical fracture, if the transition period occurs during the linear flow, two parallel straight lines of slope 0.5 appear on the pressure derivative plot. This pressure derivative behaviour can be used in calculating different reservoir parameters.