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A novel tool for designing well placements by combination of modified genetic algorithm and artificial neural network

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ABSTRACT

Well placement optimization techniques that use reservoir simulations are currently taking advantage of using the Genetic Algorithm method and involve the output of a reservoir simulation, which is the hydrocarbon recovery, and thus, the technique requires running a reservoir simulation when finding a maximum value for the recovery. For a very large field of gas, a condensate reservoir would be very time consuming, and when there is only a limited amount of time for decision making, this approach would not be a sufficient technique. Of course, the conventional, traditional trial-and-error technique requires more effort. To address this very common challenge in field development planning, we propose the concept of transferring the manual traditional technique into a novel tool technique that employs Genetic Algorithm (GA), which can be used as a plug-in software application.

This paper employs a specifically formulated Genetic Algorithm method for applications in well location optimization by introducing a newly proposed fitness function (objective function) that was constructed from basic reservoir engineering properties, i.e., permeability, porosity, oil saturation, pressure of reservoir, and thickness. Furthermore, this Genetic Algorithm method was then further extended to consider the drainage radius, existing wells, existence of faults and multiple layers, simultaneously. Hence, a software application has been developed that incorporates all of these concerns into a rapid tool.

Reservoir modeling cases of oil and gas fields were used to test the proposed method, with the intention of showing the rapidness of finding the well locations, and as an additional output, this approach could yield a higher recovery than the previous technique, overall. The oil field is for cases in which multiple wells penetrate multi-reservoirs typically and penetrate selected reservoirs in test cases. However, the gas field application is for the case of horizontal well placements in which the direction and length are the optimized parameters, which are optimized by employing an Artificial Neural Network (ANN) method for the length optimization after having the best direction obtained from the Genetic Algorithm (GA) method. The proposed method can give hydrocarbon recovery results in a much faster way and even better values than the conventional method.

1. Introduction

Determining the locations of wells is one of the critical problems in the exploitation of oil and gas fields, both in the development of new fields and in the management of mature fields. The process of determining the well locations is an optimization problem that involves gaining oil or gas as much as possible by drilling a number of wells, with the total being as small as possible. Until now, the determination of the locations of new wells has usually been conducted by using a conventional trial-and-error method, when placing coordinates at a geological or reservoir model and then running with a simulator to obtain the oil or gas recovery; this process requires experience, considerable time, and a relatively high cost. Especially when addressing oil fields that have a relatively large size, we are faced with the possibility of a remarkably large number of solutions (locations of wells), which causes the conventional methods to become ineffective and inefficient.

Furthermore, genetic algorithms in the oil industry world have been applied in various areas, starting from the optimization of pipe diameters, determining the distribution of the pressure, the detection of corrosion, and so forth, including the issue of determining the locations of the well. However, in determining the locations of the well, in general, the Genetic Algorithm (GA) has always been applied as an integrated unit with a reservoir

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simulator (Bittencourt and Horne, 1997; Dianati et al., 2002; Montes and Bartolome, 2001). In such cases, the locations of the wells proposed by the GA in each iteration will always be evaluated by using a reservoir simulator. Of course, for large size reservoirs or complex reservoirs, blind properties require considerable time to run the simulation in a reservoir simulator. Therefore, a different approach that can serve as an alternative solution to the problem is needed, and a new method based on the development of the Genetic Algorithm method is performed to provide a much more effective and efficient method of solving the problem.

This approach intention is to avoid running a reservoir simulator as the current well placement method by employing basic reservoir engineering properties and applying the genetic algorithm as an evaluation judgment. This new proposed method is basically transferring a manually placing best well coordinates at a grid system of a reservoir model during a reservoir simulation process into a computerized calculation of well placement based on reservoir engineering data.

Thus, this study uses basic reservoir engineering data to evaluate the well placements; and the GA is applied in a way that it is not an integral part of the reservoir simulator. The reservoir simulator is used at the end of the process, to validate the well locations that were proposed by the GA. The results of the reservoir simulator are then compared to those of the conventional methods.

A previous study (Ariadji et al., 2012) was still limited to the determination of the locations of wells in a one-layer reservoir, but in this study, this approach has been extended to the determination of the locations of multiple wells in a multi-layer reservoir. Moreover, this approach also has been expanded to a horizontal well direction and length optimization by combining the GA and the Artificial Neural Network (ANN) methods.

After we obtain the results in this study, then we need to validate it. All of the results in this study then will be validated by using commercial reservoir simulator, i.e. ECLIPSE which is used most commonly by reservoir engineers.

1.1. Objective of this study

The objective of this study is to develop a rapid tool that employs the Genetic Algorithms (GA) and the Artificial Neural Network (ANN) method to optimize multiple vertical wells and the horizontal well placements. The proposed method requires the same data as the manual conventional method for reservoir data, i.e., porosity, permeability, thickness, saturation, and pressure in the format of a reservoir model grid map, for developing the GA objective functions. At this moment, this study does not involve the presence of fault and stress distributions.

1.2. Methodology approach

The basic reservoir engineering properties of a reservoir model in grid distributions have the value of permeability (k), porosity (ϕ), current oil saturation (S_o), thickness (h), and current pressure (P) as required input data, and these variables would be the criteria of the optimization in finding the best well location. Based on the reservoir engineering fundamental principles, as a logical consecuence, for a vertical well placement case, the best location is where all of the above parameters are at their highest values at a certain coordinate, but typically, this location is almost impossible to find. Thus, a logical consequence is that the multiplication of all of the parameters would be the standard approach to comparing each property parameter in the best way. In addition, in a multi-reservoir field, there are criteria for the selection of reservoirs that have potential to be perforated for production. Moreover, we consider that the well drainage radius and the fault boundary would be needed. On the other hand, for a horizontal well placement case, two variables must be optimized, i.e., the direction and length of the horizontal well segment. Consequently, such limited multiplication of the reservoir engineering property approach is not sufficient, and thus, we need an additional method to involve the second variable, i.e., the horizontal well length, which can be accomplished by applying the neural network approach to relate the input (the length of the horizontal segment) and the output (the hydrocarbon recovery) while using as limited an amount of data as possible. Thus, we propose a combination of genetic algorithms and artificial neural networks to automatically process all of the above considerations and to optimize for the best well locations.

The proposed method employs the multiplication of the basic reservoir engineering properties as a new objective function for the genetic algorithm method. To validate the results of the proposed method's best locations, a reservoir simulation is then conducted to compare the results with those of the conventional methods in terms of hydrocarbon recovery. The results of the conventional methods are obtained directly from the previous reservoir studies on the respective fields. The overall methodology is performed as depicted in Fig. 1.

1.3. Description of the reservoir model for testing the method

This reservoir model is generated from a real oil field, namely, X field, that has a formation of generally dominated by sandstones, and the depositional environment of fluvio deltaic shallow marine. This sandstone is very fine to very coarse grained, angular to rounded grained, with poor to well sorting, hard but some parts are not consolidated properly.

The X field has an average value of good permeability of 147 mD, a medium porosity of 12.4%, a sufficient oil saturation of 35.5%, a thin layer thickness of 1.86 m, and a reservoir pressure of 171 bar. The reservoir characterization indicates that the permeability and oil saturation are quite heterogeneous. The reservoir model has a total number of layers of up to 12, in which the optimum locations of wells for 2 conditions will be sought: the first condition is with all layers perforated, and the second condition is with selective perforated layers based on specified criteria. The model of the reservoir itself has been scaled up into 283,912 grids. Fig. 2(a)–(c) shows the distribution of the permeability, pressure, and oil saturation; grids with dark colors have lower values, while grids with bright colors have higher values.

In X Field, the depletion mechanism is dominated by the water drive. In addition to the water drive, this field also has a gas cap, which serves as its additional depletion mechanism.

1.4. Application of the genetic algorithm for simultaneous vertical well placement

The Genetic Algorithm (GA) is an optimization method for obtaining the optimum solution to a problem that is formulated in terms of mathematical functions. Compared with other optimization

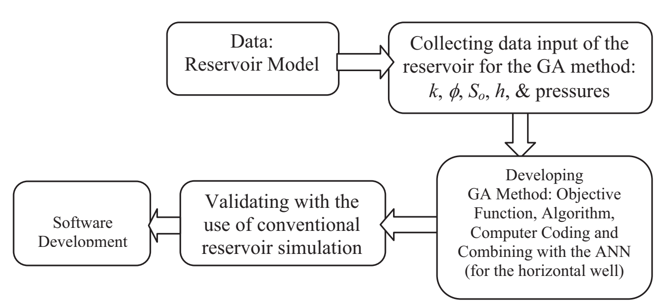

Fig. 1. Research methodology.