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A METHOD FOR COMBINE OBJECTIVE FUNCTION IN ASSISTED HISTORY MATCHING OF PETROLEUM FIELDS

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Abstract. *History matching process consists of finding the best combination of properties in order to minimize the difference between calculated and observed data. In a typical process it is necessary a visual and subjective judgment on the quality of the matching. Using assisted history matching, the quality of the results is obtained by an objective function, that is a measure of the mismatching. The composition of objective function is a difficult task when dealing with data with different order of magnitude or different in nature, such as production and pressure data. The common approach is the combination of the several parameters using a simple average between them or the inclusion of constant weighting coefficients. The combination of objective function in this way is particularly complex when several parameters (wells, for example) are involved and the difference between the data is significant, for instance wells with low rate and wells with high rate. In this paper, a flexible and adaptive form to compute weighting coefficients for compose the objective function is proposed. The rule for the computation is defined during the process and is dependent on the characteristic of each parameter. In order to measure the efficiency of the method, results obtained with combined objective function using the proposed approach are compared to those obtained with combined objective function using fixed weights. The advantage in terms of computation time is also evaluated.*

Keywords: reservoir engineering, reservoir management, assisted history matching

1. Introduction

The main objective of reservoir characterization is to build a reliable simulation model to be used in production forecasting. Although with the modern characterization techniques, such as 4D seismic, seismic inversion, well logs and advanced geostatistical methods, is very difficult to obtain a completely accurate model. To improve reservoir characterization, production or dynamic data, such as pressure, oil and water rate water cut are included to the process. This procedure is known as history matching. The outcome of the history matching is that the obtained model reproduces the observed data. Integrating dynamic data into reservoir characterization process is an inverse problem. Generally, a high level of complexity due to factors such as nonlinearities and a large amount of variables is involved.

History matching can be divided in two main steps: the first step is a global match in which properties in whole reservoir are changed. The second step consists of tuning the process changing local (generally near wells) properties to match wells pressure and production.

Traditionally, history matching is performed by a trial and error approach. In this form, a lot of manual task is involved, such as change simulation model, run simulations, plot curves and compare to observed data, and so on. Generally, subjective judgment is present, mainly in the quality of the match. Completely manual process is very tired and time consuming. On the other hand, completely automatic process is very difficult in the practice. Assisted history matching is an intermediate approach. The main objective is to automate those manual tasks, such as simulation model modifications, run simulations, comparison of observed and simulation data, etc. The choice of properties to be changed, for example, is the responsibility of the professional. The main purpose of assisted history matching is decrease the "human" time associated with the process (Arenas, 2001).

The quality of a history match is measured by the distance between the history and the results of simulation. To assessment of misfit between simulated and observed data (history), the most of works in the literature use the least-squares method (Schulze-Riegert, 2001; Schulze-Riegert, 2002; Kretz, 2002; Feraille, 2003)

A common difficult in the history matching process is the composition of the objective function. This difficult is aggravated when several parameters, such as pressure, oil rate, water rate is involved, or when a large number of wells must be adjusted. A common practice is the use of fixed weight coefficient. Feraille et al. (2003), for example, classified the wells with similar behavior, that is, with similar rate and pressure, and they used constant weights for the groups of wells. Rahon (1999) used normalization coefficients for compose objective function incorporating water rate, water saturation, and pressure. (Wen et al, 2002) applied weights coefficients to compose fractional-flow rates (water cut) at production wells and water-saturation spatial distribution at a given time in two-phase-flow (oil/water) reservoirs. Landa et al. (2003) assigned weights for each data type and for each well are assigned as a function of the number of data points and of the uncertainty associated with each type of measurement. According (Brun, 2001), in general is very difficult to know what value to use. They have checked the influence of various weights doing several history matches.

2. Methodology

The objective function is the target of a history matching process. The goal is its reduction as much as possible. Several parameters can compose the objective function, such as field pressure, field oil rate, field water rate, well pressure, well oil rate, well water rate and so on. For the composition, is necessary to know the distance between the simulated curves and observed data related to each parameter include into the process.

The distance between simulated and observed data is calculated using least-squares method, according the follows equation:

$$D = \sum_{i=1}^{n} (H_i - S_i)^2 \tag{1}$$

where n and H is the number and value of observed data, respectively, and S is the simulated data.
For compose the objective function from several parameters, the approach proposed in the present work to compute the weight coefficients follows the next equation:

$$w_{j,p} = \left(\frac{D_{j,p}}{D^H} \right)^k \tag{2}$$

where j is the number of simulations of a given search and p is the number of elements (or parameters) that compose the objective function. These elements can be multiple phases (oil, water and gas rate, for example) and pressure associated to the total field, or a given specific parameter (water rate, for example) associated to several wells. D^H is the highest deviation among a series of deviations ($D_{1,1}$, $D_{2,1}$… $D_{j,1}$; $D_{1,2}$, $D_{2,2}$… $D_{j,2}$; $D_{1,p}$, $D_{2,p}$… $D_{j,p}$) associated to a given parameter and k is an exponent. If k=0, the weight coefficient is equivalent to the arithmetic average of the distances, that is, weight coefficients are equals 1. If k=-1, the weight coefficient is equivalent to the harmonic average of the distances.

In this way, weighting coefficients (wi) are not previously defined as fixed value. This guarantees the same importance of each parameter in the composition of the objective function during all process.

The objective function is then composed as:

$$OF_j = \frac{\sum_{i=1}^{p} (w_{j,p}).(D_j^N)}{\sum_{i=1}^{p} w_{j,p}} \tag{3}$$

The distance D is normalized with respect to the distance of the base model, such that:

$$D_j^N = \frac{D_j}{D_{Base}} \tag{4}$$

The optimization algorithm used is this work is based on direct search method, which do not requires any gradient information, that is, the computation of derivative of the objective function is not necessary. The method uses only the objective function value to determine new search directions in a space solution composed by grid points. Each point in the grid corresponds to a set of property modifications. The optimization method consists of a series of exploratory and linear search.

The main advantage is the guarantee of convergence even in cases with significant non-linearities of the objective function or discontinuities in the search space, where gradient-based methods normally do not works very well. Some details of the algorithm can be found in (Leitão and Schiozer, 1998; Leitão and Schiozer, 1999) and Maschio and Schiozer (2004).

3. Application

The methodology proposed in this paper was applied in a real field of Campos Basin. The field is represented by a simulation model composed of a grid of 52×30×6 blocks. The field is drained by 37 producer wells and 13 injector wells.

The application is divided in two steps. The first is a global history matching and the second is a local (wells) history matching. In the first step, the objective function was composed by field oil rate (Qo), field water rate (Qw) and field average pressure (Pressure). The process was carried out using fixed weight coefficients (Method 1, for simplicity M1) and using the proposed method (Method 2, for simplicity M2) and the results obtained through both methods are compared.

The properties used in the match were porosity (POR), net to gross ratio (NTG), horizontal permeability (PERMI) and vertical permeability (PERMK). In Tab. (1) appears, lower and upper multipliers, as well as the number of intervals, for each properties used in the field history matching.

Table 1 - Properties and multipliers used in the field history matching

	POR	NTG	PERMI	PERMK
Lower Multiplier	0.85	0.7	0.4	0.3
Upper Multiplier	1.15	1.3	2.0	2.5
Intervals	10	10	16	16

In the second step, three wells (W07, W15 and W40) were chosen for water rate history match. Therefore, the objective function, in this case, was composed combining the water rate of the three wells. The properties used in the match were PERMI and PERMK. The minimum and maximum multiplies were 0.2 and 2, respectively, with 9 intervals for the three wells.

For M1, the weight coefficients used for Qo, Qw and pressure were 1, 6 and 3 respectively, and for M2 was used k=-0.5.

4. Results and Discussions

Firstly, the performance of the proposed method is evaluated for a global history matching, comparing it with the method that uses fixed weight coefficients. In Fig. 1 is presented the reduction of distance between simulated and history for Qo, Qw and Pressure, using Method 1 (M1) and Method 2 (M2). It can be seen that M2 converges more fast than M1. The number of simulation related to M1 (50) is very lower than the number of simulation related to M2 (103), that is, lower than half. On the other hand, the reduction of distance is practically the same. For pressure, M1 produces a smaller reduction.

In Figs. 2 3 and 4 are shown oil rate, water rate and average field pressure match, respectively, for the two methods M1 and M2. Oil rate match is exactly the same, that is in according to the reduction of distance for oil rate (Qo) shown in Fig. 1. Water rate and field pressure are slightly different and this signifies that the better combination of the properties found by the two methods was not the same. In Tab. (2) are presented the multipliers found by the methods M1 and M2 for each properties included in the process.

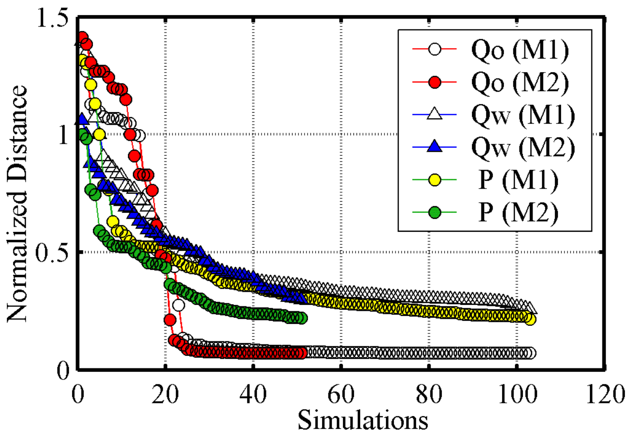

Figure 1 - Reduction of distance for Qo, Qw and Pressure

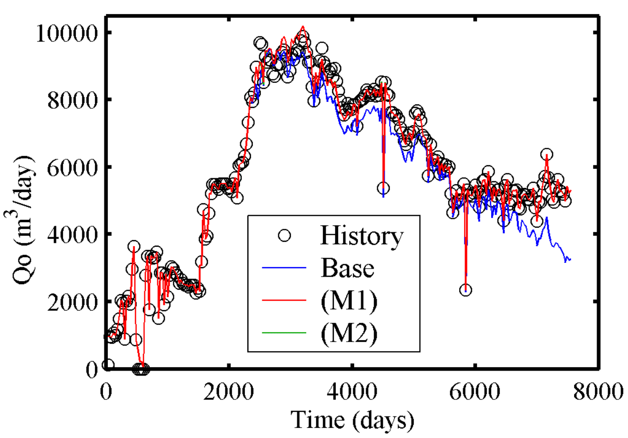

Figure 2 - Oil rate match

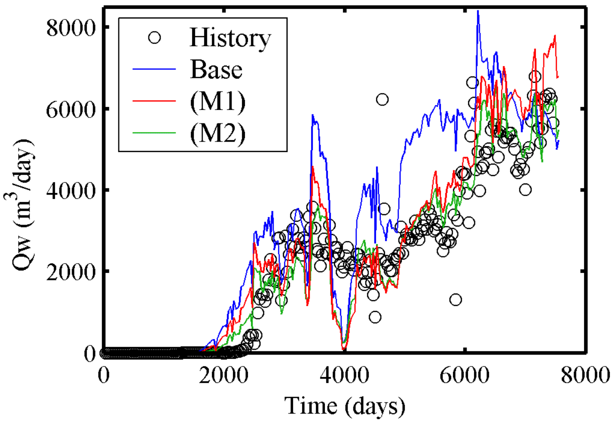

Figure 3 - Water rate match

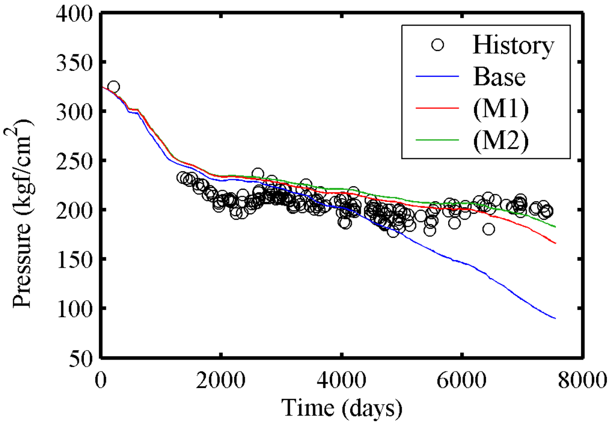

Figure 4 - Reservoir pressure match

Table 2 - Properties multipliers found by the methods M1 and M2

Method	POR	NTG	PERMI	PERMK
M1	0.94	1.24	2.0	0.3
M2	0.97	1.18	1.9	2.0

Considering the curves presented earlier, the better results, obtained in the global matching was adopted as the model for the next step, that is, the local match. The reduction of distance between simulated and observed Qw for the three wells is shown in Fig. 5. Also in this case, the Method M2 converged faster than M1, but the difference is lower than in the global match. The final distance is the same, indicating that the combination of properties for the match was the same. The final field match is presented is Figs. 6, 7 and 8. Field water rate match was improved with the well match, mainly in the initial period of water production, approximately 2000 days.

An aspect that can be observed in Fig. 5 is the small rate of decrease of the distance after 45 simulations. This occurs because the local change associated to a given well do not causes significant influence in other wells.

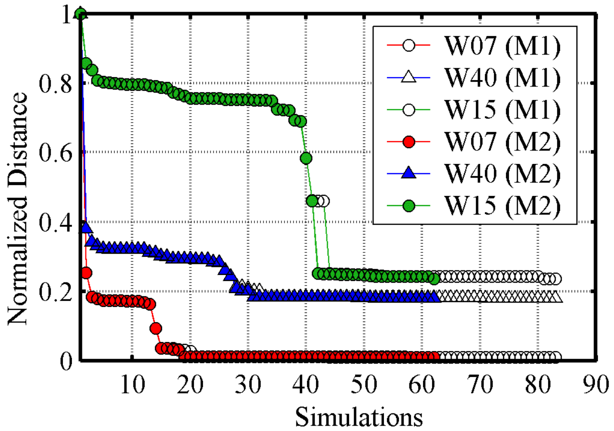

Figure 5 - Reduction of distance of Qw for the three wells

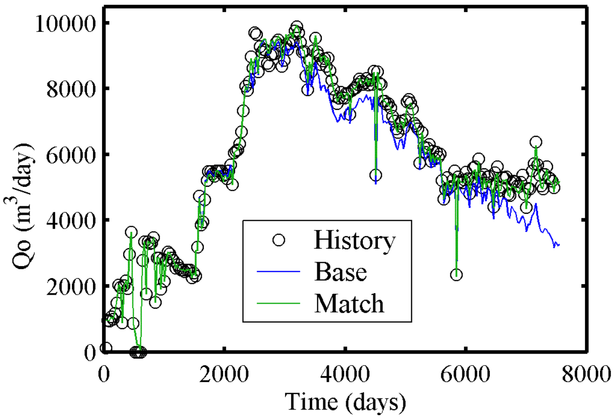

Figure 6 - Final oil rate match

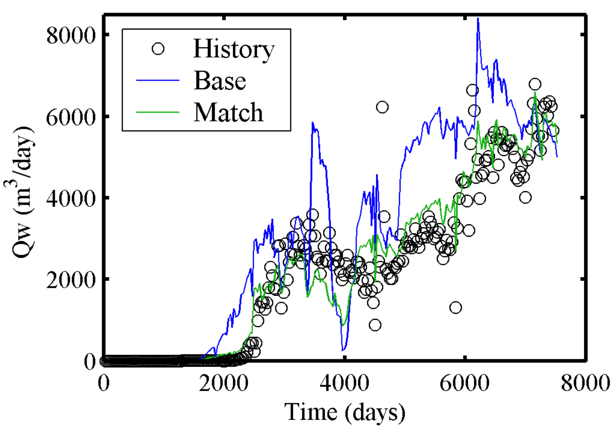

Figure 7 - Final water rate match

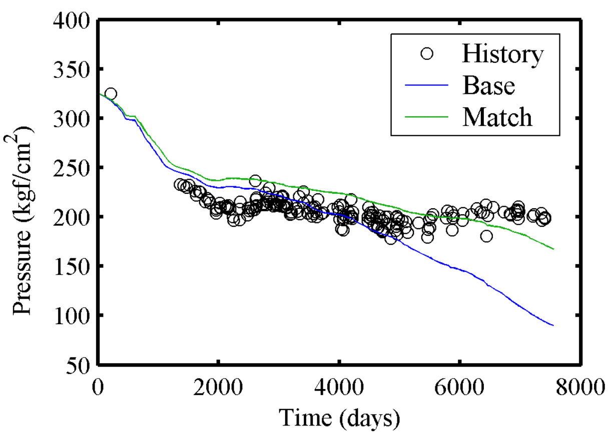

Figure 8 - Final field pressure match

5. Conclusions

The choice of weighting coefficients for composed the objective function influence the history matching process. The results presented in this paper showed that the proposed method for computation of weighting coefficients was relatively efficient for the tested cases, when comparing to the method that uses fixed weights (M1). In the field history matching, the proposed method (M2) converged practically two times fasten than the another method and the quality of the matching was very similar in the two cases. In the wells matching, although with a smaller difference, M2 also converged fasten than M1.

6. Acknowledgement

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