F04

History Matching of Reservoirs by Modifying Fault Properties Using 4D Seismic Results - A Synthetic Study

R. Villegas* (University of Leeds), C. MacBeth (Heriot-Watt University) & A. Benguigui (Heriot-Watt University)

SUMMARY

This work we proposes a new integrated methodology which includes geophysics, time lapse seismic data, and history matching to improve the spatial distribution of the fault properties. We also take into account during the history matching the prior probability distribution of the transmissibility obtained using 4D seismic and a prior reservoir simulation model. For updating the fault transmissibility values into the simulation model, we consider the prior probability distribution of the transmissibility values generated using the results of a previous methodology which uses time lapse seismic data and also involves the estimation of fault and matrix permeability to estimate the transmissibility multiplier (Manzocchi et al., 1999 and 2002). These data are then processed during the automatic history matching methodology proposed in this work to achieve fully structured 3D profiles of the underlying reservoirs which comply with the available prior information and which honour production data. Here we apply our methodology in a synthetic but realistic case.

The goal in a history matching process is to generate one or more models which can provide more accurate performance predictions for optimizing the future development plan of the reservoir. During the history matching, the key factor is to understand the interaction between parameters, uncertainty, measurements, and strategic business decisions. For many years already, and even more recently due to the increasing impact of the oil production on the worldwide economy, the research in the area of reservoir compartmentalization, specifically fault transmissibility estimation, in a history matching process has become an important problem in petroleum engineering. Fault transmissibility depends on fault permeability and it modifies fluid flow behaviour which is reflected in bottom hole pressures and production data at the well locations. In particular, it can cause compartmentalisation. Changes in fault permeability introduce disruptions to the pressure and saturation fields, which in turn control the time lapse seismic signature within each compartment. In conventional studies, the fault transmissibilities included in the simulation model to represent the behaviour of faults are based on geological understanding and are uncertain because of the sparse nature of well data used in their estimation. As a consequence, during the conventional history matching process frequently the prior fault transmissibilities are modified in order to match the production data without integrating in a quantitative way the interpretations and uncertainties of others disciplines.

In this work we propose a new integrated history matching methodology which includes geophysics (in particular time lapse seismic data) to supplement and better resolve the spatial distribution of the fault properties. We also take into account the prior probability distribution of the transmissibility estimation using 4D seismic and a prior reservoir simulation model. For updating the fault transmissibility values into the simulation model, we consider the prior probability distribution of the transmissibility values generated using the results of a previous methodology which uses time lapse seismic data and also involves the estimation of fault and matrix permeability to estimate the transmissibility multiplier (Manzocchi et al., 1999 and 2002). These data are then processed during the automatic history matching methodology proposed in this work to achieve fully structured 3D profiles of the underlying reservoirs which comply with the available prior information and which honour production data. Here we focus on a detailed description of this new methodology to improve the fault description of any reservoir type and give further results.

From a mathematical viewpoint, our new technique can be described as a strategy for solving an inverse problem by 'parameter inversion'. The goal of this novel technique is to incorporate the prior information about the faults from the geologic model, and 4D seismic into an iterative process based on statistics. We apply our methodology using a synthetic but realistic black oil simulation model with water flooding, 3 injection wells (I1, I2, I3) and 3 producer wells (P1,P2,P3). In this work the reference data are generated using a streamline simulator on the reference model. We evaluate the impact of fault properties and their prior statistic model on reservoir production by first evaluating the input data, then doing a history matching flow simulation for modifying this model of fault-compartmentalised reservoirs based on both production and 4D seismic results. We use the new 4D fault transmissibility values and their probabilistic distributions estimated using the above described methodology which has been developed previously. The methodology proposed in this work and the results obtained are displayed in the workflow presented in Figure 1. The input data are the possible range of transmissibility values (including mean value) and the initial simulation model which includes the original transmissibility values and the reference pressure production data. In more details, the possible transmissibility values are the minimum and maximum values as well as the most probable value in each cell of the model obtained from time lapse seismic results considering that 4D seismic responses are primarily due to changes in fluid saturation. In the next step, we introduce an objective function, depending on the water production rate and pressure, to evaluate and control the data misfit between simulated and reference data. We evaluate the data misfit corresponding to our input data (original, maximum, most probable and minimum values of transmissibility) and it is shown that minimum transmissibility values produce the better data fit. Later we carry out the automatic history matching by estimating cumulative density functions which are generated for each cell assuming a triangular probability distribution. These cumulative density functions are obtained by integrating the piecewise defined prior probability density function. During the history matching the transmissibility values are modified automatically in the cells next to the faults in x,y and z direction and using a random number generator and the cumulative density function generated in the prior step which considers the time lapse seismic results. By doing this we reduce the pressure production data misfit by changing the transmissibility values and by considering the uncertainties associated to the transmissibility estimates.

In the presented work we achieve improved fault properties and we define methods for history matching using both production and 4D seismic constraints, which will provide a more robust basis for production forecasting. This work combines data and concepts from history matching, fault-related fluid flow, and geophysics, with a considerable focus on integration and data management.

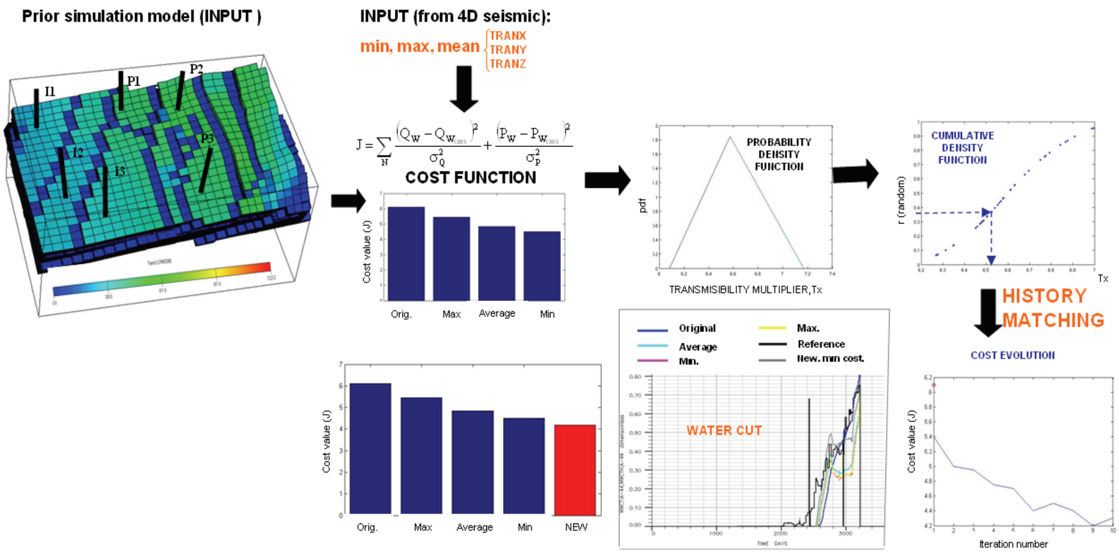

***Figure 1** Workflow of History Matching process considering the prior probability distribution in fault transmissibility values using 4D seismic results.*

References

- Manzocchi T., Walsh J., Nell P., Yielding G., 1999, Fault transmissibility multipliers for flow simulation models. Petroleum Geoscience, Vol. 5, pp. 53-63.
- Manzocchi, T., Heath, A.E., Walsh J.J. and Childs, C. [2002] The representation of two-phase fault-rock properties in flow simulation models. Petroleum Geoscience, 8, 119–132.