Information-analytic system of drilling maintenance on the base of parallel computing

Yu.B. Lind¹, E.I. Zairullina², L.R. Minikeeva²

¹ BashNIPIneft LTD, 86/1 Lenina street, Ufa, Russian Federation
² Bashkir State University, 32 Zaki Validi street, Ufa, Russian Federation

LindUB@bashneft.ru

Abstract. Aspiration for oil recovery increase and activity diversification of oil companies leads to necessity in well stock extension and well program complication, as well as re-equipment of oil-rigs and drilling service outsourcing. This in its turn causes need in overhaul of existing system of drilling maintenance and control. To solve this problem it is proposed to develop an information-analytic system which allows formalizing and reducing to a common denominator principles and knowledge used in calculations in the process of drilling. Large amount of data, complexity of used algorithms and calculation time limits cause necessity of high-performance computer systems use.

Keywords

Parallel computations, drilling process, information-analytic system, database, artificial neural network.

1 Introduction

Construction of oil and gas wells is a basic process in the chain of actions for hydrocarbons extraction. Drilling of each well is carried out on the base of planning documentation for its construction; both technical and economic parameters of drilling, as well as its environmental safety and trouble-free construction, depend on correctness of data contained in the project.

The main purpose of this work is development of information-analytic system for calculations during planning of wells construction in Bashneft Company, which ought to provide for effective interaction between data flows, algorithms of calculations and used hardware.

To achieve this object it is necessary to solve the following practical problems:

1) development of an uniform relational database of field data on wells drilled in all fields and management system of this database;
2) development and implementation of a science-based methodology for planning of directional and horizontal wells profiles;
3) prediction of possible troubles occurring during wells construction;
4) optimization of drilling fluids composition and management of their properties during drilling process;
5) creation of a model for paralleling of computational process and parallel implementation of proposed algorithms;
6) development of an uniform software with intuitively clear user interface, which will issue on the basis of used algorithms valid recommendations for planning of each well depending on its geological and mining conditions.

Information-analytic system can be dynamically extended by adding of new modules in accordance with assigned tasks without loss of its functionality.
2 Model for paralleling of computational process

Processing of large amount of data, complexity of used algorithms and calculation time limits cause necessity of high-performance computer systems use. A three-level model of paralleling is proposed for assigned problems [1]:

1) paralleling on database, i.e. independent processing of different data blocks; 
2) detection and use of inner parallelism of the problem; 
3) decomposition of used algorithms.

Effective combination of these levels and their realization on the base of MPI paradigm provides for rise of calculation accuracy and implementation of complex algorithms for prediction and analysis.

3 Database of field material

Effective prediction of troubles and simulation of drilling fluid parameters require comprehensive analysis of information on earlier drilled wells. To achieve this object a database on drilling fluids and troubles, as well as data manager, have been constructed.

The database has a relational structure, which is convenient for filing and mapping of field data (fig. 1), and allows to exercise remote access to field data by means of a local network.

At present the database contains data on drilled wells in Bashneft Company oilfields (sample size exceeds 32000 wells).

![Database structure](image)

Fig. 4. Database structure.

When using parallel computing access to the database is performed by “master-slave” strategy: a control process (master) performs data interaction, and the rest (slaves) – data processing.
4 Planning of profiles for directional and horizontal wells

Methods of horizontal wells profiles planning are reduced to calculation of geometrical parameters which determine position of profile elements (vertical, directional, horizontal and curved sections), and graphical layout of a well profile.

Figure 2a represents results of program testing for construction of an S-shaped 3-interval profile, and 2b – for a J-shaped 5-interval profile. Here I-V are sections of the well profile, Hpr is depth of the productive formation top, hi (i = 1, ..., 5) are vertical projections of profile sections, ai (i = 1, ..., 5) are horizontal projections, rj (j = 1, 2) are radiuses of curvature for drift angle sections, A is a horizontal divergence, TVP is producing formation entry point.

Further the program calculates load capacity of the rig for constructed profile [2]. Paralleling of computational process is proposed to be realized with the aid of developed three-level model. Now there are implemented two levels of parallelism: data paralleling on different oilfields, well platforms and multilateral wells, and use of inner parallelism which consists in independent consideration of well boreholes with control of their non-intersection.

It is planned further to carry out optimization of well profile by rig capacity minimization with the use of geometric parallelism principle. So, the third level of parallelism will appear, and it will consist in genetic algorithm paralleling during minimum search [3].

5 Prediction of troubles during well construction

Drilling of oil and gas wells is often accompanied by troubles (drilling fluid loss, water flows and shows, slide-rocks and caving) which cause significant time and material costs and represent one of the main factors of accidents. It is possible to lower probability of troubles appearance or to prevent them at all at the stage of well planning due to valid selection of composition and properties of a drilling fluid as well as characteristics of working operations. And this in its turn can be realized only by means of simulation and prediction on the base of information on earlier drilled wells.

To estimate spatial location of wells and trace tendencies of troubles spread, software for construction of maps for troubles intensities has been elaborated. Each map is based on database information and represents a set of markers which have plane coordinates and correspond with different classes of troubles intensities (from none to disastrous) (fig.3).

On the basis of this procedure results clusterization of the whole map is carried out. It makes possible to refer any new well to one of these classes. Depending on this forecast, recommendations on type and properties of drilling fluid and characteristics of technological operations in a new well are being issued.
An important characteristic feature is that all the required information is designed coordinates of the new well. Paralleling of computation process is realized by means of suggested three-level model. Paralleling on data includes independent consideration of oilfields and troubles types. Inner parallelism of the problem consists in the fact that stratigraphical horizons are made of rocks with different physical and mechanical properties, and this allows to examine them separately.

Finally, decomposition of used algorithm reduces to arranging of all troubles on four classes and to realization of geometric parallelism principle during clustered maps construction. Testing of developed software on already drilled wells of Bashkortostan oilfields demonstrated agreement of forecast and actual values in more than 80% of cases and this shows adequacy of used algorithm.

6 Optimization of drilling fluid composition and management of its technological parameters

Quality of a drilling fluid and accordance of its parameters with requests of hydraulic program is an important condition for increase of technical and economic indices of well construction. However during well deepening properties of a drilling fluid undergo significant changes due to physical and chemical transformations and ingress of dash into fluid. One of solutions of this problem consists in control of drilling fluid properties, which is possible both at the stage of preparation (by optimization of its initial composition) and in the process of well construction (by real-time regulating of fluid’s basic properties).

Mathematical model of drilling fluid technological parameters has the form of regression equation. Its coefficients are being found on the basis of experimental data. For optimization of drilling fluid composition within given intervals of properties, it is necessary to solve an inverse problem. That is on the base of constructed mathematical model to determine such fluid composition, technological parameters of which hit given intervals and which minimizes a chosen technological criterion of optimization.
Management of drilling fluid properties during well construction is being conducted by means of its interval chemical treatment, i.e. the problem is reduced to determination of quantitative composition for recovery of desired state of circulating system, and this is made by solving the inverse problem with two sets of data: actual and required values of technological parameters.

Software which realizes this algorithm was tested for inhibited drilling fluid developed in BashNIPIneft. Tests have showed adequacy of constructed models (Table 1).

<table>
<thead>
<tr>
<th>Technological parameter</th>
<th>RV, sec</th>
<th>PV, mPa·sec</th>
<th>DSS, dPa</th>
<th>FC, ml</th>
<th>SSS-10s, dPa</th>
<th>SSS-100m, dPa</th>
<th>n(p)</th>
<th>n(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation</td>
<td>32.5</td>
<td>11.3</td>
<td>62.1</td>
<td>11.1</td>
<td>24.3</td>
<td>36.3</td>
<td>0.54</td>
<td>0.30</td>
</tr>
<tr>
<td>Experiment</td>
<td>33.4</td>
<td>10.5</td>
<td>57.9</td>
<td>12</td>
<td>24</td>
<td>36</td>
<td>0.54</td>
<td>0.28</td>
</tr>
<tr>
<td>Relative error, %</td>
<td>2.7</td>
<td>7.6</td>
<td>7.2</td>
<td>7.5</td>
<td>1.3</td>
<td>0.8</td>
<td>0.0</td>
<td>7.4</td>
</tr>
</tbody>
</table>

Parallelizing of computing process is being realized by means of suggested three-level model. Parallelizing on data includes independent consideration of different types of drilling fluids. For each of them laboratory experiments are being conducted for several values of temperature and variants of recipe. Inner parallelism includes consideration of mutually independent technological parameters of the fluid. Finally, decomposition of problem solving algorithm is reduced to realization of a parallel variant of genetic algorithm during inverse problem solution.

7 Conclusion

United software has been developed which combines possibilities of all above-listed modules and issues well-founded recommendations on designing of each concrete well depending on its mining and geological conditions. The software provides for use PCs as well as multiprocessor computer systems and has a convenient interface which allows to use it for both engineers in research institutes and drillers in field conditions.

Computer experiments with the use of a cluster of Bashkir State University proved efficiency of proposed model (Fig.4).