Influence of grid-orientation effect on modeling of Iraqi oil field: case studies

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Abstract. Reservoir simulation models are utilized by oil and gas companies with a purpose to develop fields. Expansions and improvements in simulation software have lessened the time to develop a model. Simulating the reservoir aims to realize fluid flow, physical, and chemical procedures happening in a hydrocarbon reservoir adequately well for the reason of improving hydrocarbon recovery under various working stipulations. Grid-orientation effects are complicated problem in numerical reservoir simulation. These influences were coming when utilized of numerical utilization mechanism to conditions characterizing physically inconstant displacement procedure. These impacts happen in an assortment simulation of inappropriate and favourable mobility ratio displacements. The current study presents a building static and dynamic model and suggests a development plan for the reservoir under study and change the orientation of the grids to examine the effects of these changes on the values of oil production rate, water cut, pressure, cumulative oil production, and recovery factor. The case studies for an Iraqi oil field which is located in the South East of Iraq. Different values of recovery factors were obtained when the orientation of the grids had been changed.

1. Introduction

Grid-Orientation Effect (GOE) is a serious problem cannot be ignored because it is observed even in simple reservoir geometry such as radial displacement. Numerical reservoir simulation analysis has been applied to solve this problem in oil production. However, the grids orientation (parallel and diagonal) has a significant effect on the accuracy of computational grids results in oil recovery. In the
same way, the mobility ratio has also influence to develop the GOE problem. The GOE problem has expanded and developed when the mobility ratio of displaced fluid is less than the mobility ratio of displacing fluid (unfavourable) and also observing this difficulty will develop likewise when the transition zone is short [1]. Therefore, a robust computational analysis has to develop to evaluate this effect on oil field.

This problem has been studied in many papers. Many methods have been proposed to study Grid-Orientation Influence. However, it is not any common method for resolving this issue, but there were many trials to reduce the effect. Todd, ODell and Hirasaki [2] presented the use of two-point upstream mobility weighting formula in place of single-point upstream approximation to minimize numerical diffusion of flood foregrounds and cell orientation errors. Saturation contour and oil recovery have been used to measure the reduction of grid-orientation result at mobility ratio between 0.5 and 10. The results showed reduction of the error. In addition, it was found at unit mobility ratio breakthrough time, oil recovery and saturation contour converge to the correct value when finer grids were used. Despite that fact, there was little difference in oil recoveries for parallel and diagonal grids at high mobility ratio which was an indicator of long transition zone. Coats, George, Chieh and Marcum [3] used gradually finer parallel and diagonal grids ranged from 16*16 diagonal grid and 22*22 parallel grids to examine grid-orientation mistakes. The study was applied on steam injection of a 5 spot with a mobility ratio of about 500. It also was explained that the impact of mesh sort on evaluated oil recovery was lesser than its impact on breakthrough time. The outcomes confirmed that the estimated oil recovery curves from parallel grids were equivalent in shape and quite lesser than those estimated from diagonal grids. However, the study did not succeed to determine which grid type gave the correct outcome. Holloway, Thomas and Pierson [4] proposed the usage of two-point weighting scheme in calculating mobilities and used a technique contained adjustment calculated the interblock phase transmissibilities. The study tried to minimize mesh direction influence on calculated numerical outcome in finite difference reservoir simulation. The results showed that neither two-point mobility weighting nor the transmissibility modification was suitable to remove cell orientation mistakes. Thomas, Lumpkin and Reheis [5] presented a model to examine the influences of grid-orientation by simulating variable bubble point issues above the original bubble point. The model used as an illustration issue of gas injection above the bubble point and explained adverse mobility ratio with short transition zone which resulted from gas movement into solution at the front. Yanosik and McCracken [6] applied a 9-point finite difference approximation in simulating of the reservoir. The result showed some improvement in reducing the effects of grid-orientation more than the previous five-point methods in unfavorable mobility ratio piston-type displacement issues. Stephen and Anthony [7] developed a weighted nine-point finite difference arrangement for Cartesian square cell mesh that provided numerical diffusion for quarter five spot discrete on grid-orientation. This method was successfully utilized in adverse mobility ratio piston-like displacement and short transition zone issues. This technique succeeded to reduce grid-orientation effect better than the previous five-point procedures. Bertiger and Padmanabhan [8] suggested the use of an alternate nine-point principle for reducing the influence of grid-orientation in finite difference issues. This method established on an extra correct integration of fluid inflowing through cell faces. The numerical outcomes were obtainable which proved that this procedure seriously reduced the influence of mesh orientation in identical and non – identical grids over the earlier studies which did not provide sufficient outcome within the case of non – uniform grids. Chen, Durlofsky, Engquist, and Osher [9] utilized higher order finite difference approaches for modeling miscible and immiscible displacement procedures. They searched on a second order total variation diminishing (TVD) scheme and a third order essentially non-oscillatory (ENO) method. These methods accurately resolved displacement fronts and thus obtained more effective solutions than do first order methods. In addition, using a higher order method, fewer grid blocks can be used to achieve the same precision as a first order method. Wolcott, Kazemi, and Dean [10] presented new advanced method which used a nine-point construction of the saturation equation and pressure with a third order total variation diminishing (TVD) arrangement. The procedure reduced cell network errors (even when using coarse grids) and numerical diffusion.
both for miscible and immiscible drives. Chong, Syihab, Putra, and Schechter [11] offered a technique to decrease cell orientation influences on calculated numerical outcomes in finite difference reservoir simulation which included the usage of an exceptional grid-block assignment where four-sided cell blocks combined with eight-sided cell blocks. The whole area included a structured grid-block arrangement identified as the Hybrid Grid-Block (HGB). The outcome confirmed that Hybrid Grid-Block was capable of reducing the cell trend effects for favourable and adverse displacement issues of the mobility ratio. The aim of this work is to study the influence of grid-orientation on an Iraqi oil field which is one of the most important three major oil fields in southern Iraq.

2. Description of Iraqi Oil Field
An Iraqi Oil Field has been selected to study the grid-orientation effect. The location of this Oil Field is in the southern part of Iraq as shown in figure 1. The field's length is about 30 km and it is width nearly 7 km. This field discovered in 1954. Twenty wells had been drilled in the field, since then.

The study formation has two domes separated on each other by a saddle; a small dome within the north and a large dome in the south of the field. The dimensions of the north dome are 12 km long and 6 km wide, while the south dome dimensions are 18 km long and 8.5 km wide.

Stratigraphically, the formation is divided into four zones, specifically, A, B, C, and D. These zones most commonly include sandstone, shale, and low ratio of siltstone. Tidal sand and fluvial sand are kinds of sandstone. Siltstone in this reservoir is considered as non-reservoir rock. The reservoir has a non-homogeneous permeability scheme containing shale facies of low permeability and sandstone facies of high permeability.

3. Grid-Orientation Influence Study
Grid-Orientation Effect for the study reservoir of the field on simulation results as oil production rate, cumulative oil production, water cut, pressure, and recovery factor has been examined. Water injection plan for twenty years has been predicted. It is assumed the wells arrangement is a five-spot. Five-spot water flood conduct using parallel and diagonal Cartesian cell arrangements. The parallel cell arrangement is a cell which is turned parallel to the line joining an injection / production sets while the diagonal cell arrangement is a grid turned at 45° between injection and production sets. The plan includes two cases:
1 – Case 1 grid-oriented diagonal to the injection / production sets for fine grids as shown in Figure 2.

2 – Case 2 grid-oriented parallel to the injection / production sets for fine grids as shown in Figure 3.

![Figure 2. Grid-Oriented Diagonal to Injector - Producer Pairs for Fine Grids.](image)

![Figure 3. Grid-Oriented Parallel to Injector - Producer Pairs for Fine Grids.](image)

Type of the grids that used in this study is Cartesian grid has X and Y increments equal (200) m for the two cases. Statistics of the cells at any angle parallel or diagonal to the injector / producer pair differ by (nI and nJ) cells, total number of 3D cells, (nI and nJ) nodes, total number of 3D nodes, Average X and Y increments, total number of two dimensional cells, total number of two dimensional nodes, and total number of defined nodes as shown in tables 1. Simulation results for the field indicated that these results are different in each case as shown in Figures 4 and 5. The summarized results at the end of the prediction cases are illustrated in Table 2.

### Tables 1. Statistics of the Grids for Cases 1 and 2.

| Description                          | Value  | Description                  | Value  |
|--------------------------------------|--------|------------------------------|--------|
| (nI*nJ*nK) cells                    | 121*207*12 | (nI*nJ*nK) cells            | 232*231*12 |
| (nI*nJ*nK) nodes                    | 122*208*13 | (nI*nJ*nK) nodes            | 233*232*13 |
| Total No. of 3D cells               | 300564  | Total No. of 3D cells        | 643104  |
| Total No. of 3D nodes               | 329888  | Total No. of 3D nodes        | 702728  |
| Total No. of 2D cells               | 25047   | Total No. of 2D cells        | 53592   |
| Total No. of 2D nodes               | 25376   | Total No. of 2D nodes        | 54056   |
| Total no. of defined 2D nodes       | 25333   | Total no. of defined 2D nodes| 25336   |
| Average X increment (m)             | 198.7   | Average X increment (m)      | 199.28  |
| Average Y increment (m)             | 199.249 | Average Y increment (m)      | 199.45  |
Table 2. Results of the Prediction Cases.

| Recovery Factor (%) | Plateau (Year) | Field Oil Production (Total Million STB) | Field Pressure (bar) | Field Water Cut (%) | Case Number |
|---------------------|----------------|------------------------------------------|----------------------|---------------------|-------------|
| 13.593              | 9              | 292.415                                  | 196                  | 41                  | Case 1      |
| 12.366              | 7              | 279.166                                  | 200                  | 41                  | Case 2      |

Figure 4. Field oil production rate, cumulative oil production, W.C. and pressure versus date for Case 1

Figure 5. Field oil production rate, cumulative oil production, W.C. and pressure versus date for Case 2

4. Comparison of the Cases Results
The results of the reservoir simulation model for the production wells as water cut and oil production rate have been compared. It has been found that these results are different from well to another for each case because direction of the flow will change when orientation of the grids has been changed. That means the case output does not follow a consistent pattern as shown in Figures 6 and 7.
5. Conclusion
The static and dynamic model has been presented to study Grid-Orientation Effect. An Iraq oil field was selected as a case study. The orientation of the grids effect was evaluated to examine the effects of these changes on the values of the oil production rate, water cut, pressure, cumulative oil production, and recovery factor. The results are as follows.

1. The statistics of the grids will change when orientation of the grids has changed.
2. The results of simulation model for the reservoir under study as water cut, oil production rate, cumulative oil production, and pressure differ from well to well for each case when orientation of the grids has been changed. The same thing is for fine grids and coarse grids with the same rotation angle of the grids because when orientation of the grids has changed, the direction of the flow will change.
3. Initial oil in place changes when changing orientation of the grids because position of the grids and distribution of the property in the grids (as porosity, water saturation, and net to gross ratio) change, which leads to change active cells number.

4. Volume calculations differ at each angle, whereas these calculations are done by trigonometric functions.

5. There is no clear trend or relationship between the simulation results with the angle of grid oriented.

6. The Z direction has no influence when changing the orientation of the grids.

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