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Impact Analysis of Grid Upscaling on the Results of Numerical Simulation

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Abstract: Grid upscaling can reduce the number of geologic model's grids, at the same time it can match the real geosphere. For further to see the impact characteristics of grid upscaling on the results of numerical simulation, this paper study it through four respects: the method of grid upscaling, the degree of grid upscaling, the distribution regularity of plane formation parameters and longitudinal formation characteristics. With changing the grid upscaling method, single grid step, the formation plane permeability differential, and the geological model of differential between the layers. Finally, we get what we want at different conditions.

Keywords Grid upscaling; Numerical simulation; Reservoir parameter; Impact analysis

INTRODUCTION

Reservoir fine description, limited to computer storage and computing cost, has been unable to widely used in the numerical simulation[1,2]. Since the birth of grid upscaling, due to its maintaining the basic information of original formation, saving the calculation time, improving the efficiency of the numerical simulation work, it has been getting more favors of reservoir workers[3].

This article studies the upscaling of model's permeability, respectively for the grid upscaling method optimization, grid upscaling degree analysis and the formation of vertical heterogeneity and plane heterogeneity of permeability. Systemic conclusions are given, so we can provide referential materials for other reservoir workers.

RESEARCH CONTENT

Research of grid upscaling method

At present, the widely used upscaling method by reservoir workers can be divided into three categories: simple average method、composite average method and method based on the flow of three-dimensional numerical solution. This paper selects arithmetic average method (SS), geometric mean method (JH), blend of arithmetic average method (TH-SS) and non-current boundary method(FLD) as the representatives for research.

This paper constructed a concept model, whose volume is 300×300×5m3. It's longitudinal is uniformally divided into five layers and it conform to the positive rhythm geological sedimentary rule. The water injection rate is mostly the same with the oil productive capacity. The well spacing pattern is five-spot pattern. The distance between the production well is 300 m, the injection well is located in the middle of these production wells. The step is 3m×3m, so this model have 50000 grids totally. The upscaling model's step is 15m×15m without others changing, so it has 2000 grids totally.

Permeability of the geological model constructed is coarsened respectively by the selected method, results expressed as relative error, upscaling model compared with fine model, as shown in table 1:

Table 1: Upscaling model relative error statistics

Content	SS(%)	JH(%)	TH-SS(%)	FLD(%)
Recovery	0.81	0.76	0.76	0.76
Water content	2.73	2.71	2.71	1.66
Cumulative water production	0.91	0.91	0.91	0.39
Average pressure	0.07	0.08	0.08	0.03

In conclusion, within the scope of the engineering allowable error, you can freely choose upscaling method. And the method based on 3d numerical solution of flow boundary, whose relative error is smaller, is more close to the results of fine description model.

Research of the degree of grid upscaling

For the built model, on the basis of fine model, set the grid step length are: 5m×5m， 6m×6m， 10m×10m，15m×15m，20m×20m，30m×30m.And compare impacts of different degree of upscaling on the result of numerical simulation. Here, summarize recovery datas of each model, and make it a graph as shown in figure 1:

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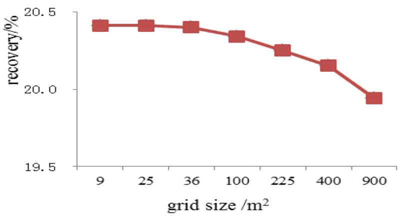

Fig.1: The relation curve between the grid size and recovery degree

As shown from the figure 1, with the increase of grid step, recovery of the model declined.

This is because when the grid was upscaled, volume of each grid increased, the water advance front changed more violently, the water/oil displacement process diverged continuous displacement process, changed to intermittent displacement. At the same grid, the big one has more oil than the small one, so the recovery decreases. The bigger grid step, the more degree of intermittent displacement, recovery decreases badly.

Water content curves of different models showed in figure 2:

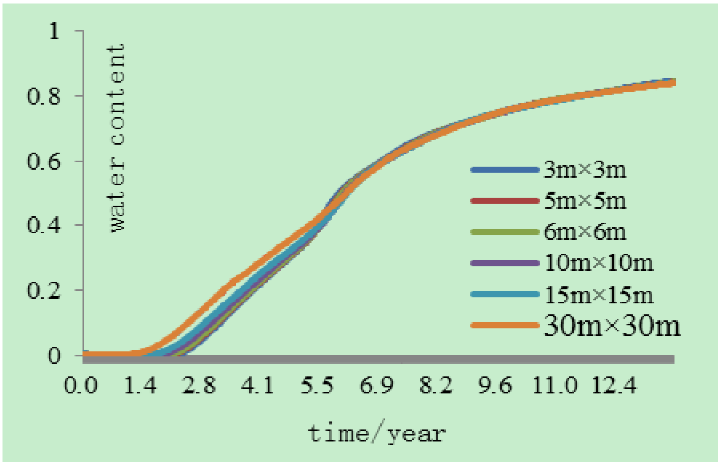

Fig.2: The water content curves change with the development time

As shown from the figure 2, when in low and medium water cut period, the bigger the grid step length, at the same time the higher water content; when in high water cut stage, the grid upscaling degree has less effect on the water content, whose curves approximately converge.

This is because water transfer in the form of grid, the pressure of water in each grid is consistent with each other. When the water saturation within a single grid reaches a certain value, water spread around. Under the same pressure gradient, pressure which have a little change, small grid is easy to achieve a high water saturation. So near the injection wells, small grids have a high water content.

Research of plane heterogeneity on the results of numerical simulation

This paper, by changing the formation plane permeability differential, set different formation conditions including 1, 3, 6, 10, 20 five kinds of differential. Recovery data are shown in table 2:

Table 2: Statistics of recovery（%）

Permeability differential	1	3	6	10	20
Before-upscaling	16.89	16.74	16.15	15.84	15.78
After- upscaling	16.65	16.2	15.98	15.6	15.53

As shown from table 2, before and after the upscaling of each model, the greater the permeability differential plane, the lower the recovery.

Here, select the model of plane permeability differential of 3 and 10 respectively, and compare their water content - recovery changes, make them to figure 3 as below: As seen from the figure 3, when recovery degree is low, the curve are almost coincidence; when recovery increases, under the same condition, the greater the permeability differential plane, the higher the water content. This is because the greater the differential, the stronger the formation heterogeneity, water is easy to find channels who has high permeability to push. So, when model has a high permeability differential, it has a high water content.

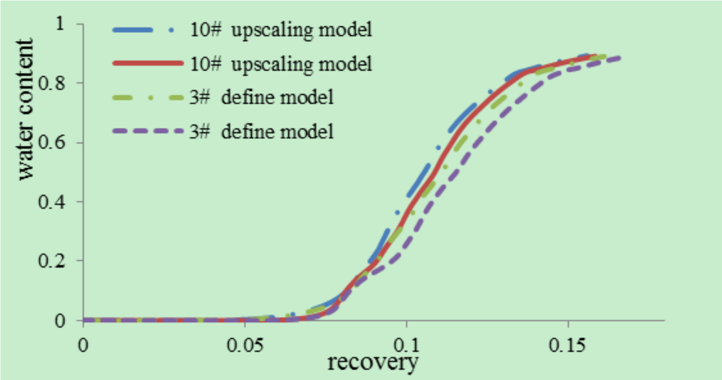

Fig.3: Curves of water content changes with recovery

Research of vertical heterogeneity on the results of numerical simulation

Build geological models, under positive and negative rhythm conditions, whose permeability differential between the layers are 1.5，2.3、4、10、20. Recovery data are shown in table 3:

Table 3: Statistics of recovery degree（%）

Permeability differential	1.5	2.3	4	10	20
Positive-fine model	20.41	20.31	20.23	19.62	19.63
Negative-fine model	20.46	20.45	20.31	19.71	19.62
Positive-upscaling model	20.34	20.25	20.15	19.57	19.57
Negative-upscaling model	20.46	20.45	20.37	19.77	19.67

As shown from the table 3, under the same rhythm and upscaling degrees, the greater the differential between the layers, the lower the recovery; recovery of positive rhythm model is lower than its fine model, and the negative ones are opposite.

For the model of positive rhythm, when the grid was upscaled, volume of each grid increased, the water advance front changed more violently, the water/oil displacement process diverged continuous displacement process, changed to intermittent displacement. At the same grid, the big one has more oil than the small one, so the recovery decreases. For the model of negative rhythm, porosity and permeability of upper layers are higher than lower layers, water on the vertical displacement is equal to the self-priming process. When the grid becomes bigger, water spread to the whole layer once reach the upper one, so it can spread to a larger area, and it's recovery is high.

CONCLUSIONS

(1)The method based on 3d numerical solution of flow boundary is more close to the results of fine description model.

(2) The grid step length has a larger influence on low and medium water cut period, but a smaller influence on high water cut stage; grid step length increases, the time of water breakthrough and recovery, in the same conditions, reduces.

(3) The greater the permeability differential plane, the lower the recovery; under the same condition, the greater the permeability differential plane, the higher the water content.

(4) Under the same rhythm and upscaling degrees, the greater the differential between the layers, the lower the recovery; recovery of positive rhythm model is lower than its fine model, and the negative ones are opposite.

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