Study on Smart Numerical Simulation Mechanism in Complex Reservoir Using Embedded Discrete Fracture Model

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Abstract. The embedded discrete fracture model (EDFM) method is used to study the mechanism model of the reservoir with a complex fracture system, and the sensitivity analysis of the development effect is carried out. The results show that: 1) the EDFM method can directly characterize the fracture morphology and fracture attributes in the reservoir; 2) Through comparative analysis of reservoir type, capillary force, and fracture development degree, it is found that different reservoir types have great differences in development effect, fracture opening has little influence on the reservoir, capillary force and fracture density have a great influence on the reservoir development effect, and with the increase of fracture density, the reservoir development effect increases significantly.

1. Introduction
In the complex fractured reservoir, the fracture forms are various and the distribution is complex. The traditional discrete fracture model takes the fracture as the boundary of bedrock grid, and uses unstructured grid to divide the grid. The division process is complex and the amount of calculation is large. Especially when the cracks are close to each other, the quality of mesh generation is poor, resulting in calculation error [1].

In this regard, Lee [2] applied embedded discrete fracture modeling to simulate the reservoir with complex fracture system. EDFM method can accurately and effectively simulate any complex fracture in the reservoir, and can be used in any conventional reservoir simulation software to simulate any complex fracture system. Through this method, the fracture geometry and properties can be directly and accurately embedded in the configured matrix block, There is no need to use local grid refinement (LGR) or unstructured grid technology (these modeling technologies usually require a lot of computing resources to build a single well model, which may make the analysis of these very complex fracture systems more complex) [3]. After that, Moinfar [4] derived the fully implicit component model based on the embedded discrete fracture (EDFM), and further improved the model. It can express the fracture at the same time, and the fracture can be any angle, which can well describe the fracture complexity and reservoir heterogeneity in the model.
In order to better study the complex fractured reservoir, this paper uses the embedded discrete fracture model (EDFM), based on the reservoir numerical simulation mechanism model, studies the seepage characteristics and seepage mechanism of the fractured reservoir in detail, and carries on the sensitivity analysis on its influence on the development effect, which provides a reference for the study of using the embedded discrete fracture model to study the complex fractured reservoir Scientific and reasonable development technology policy to provide a theoretical basis.

2. Seepage characteristics and displacement mechanism
The diversity of reservoir space in fractured reservoirs leads to the great difference of fluid flow conditions in their pore network, which makes these reservoirs have multiple pore structure characteristics. For the convenience of research and evaluation, according to the characteristics of pore structure and fluid flow in it, the multiple porous media is simplified as dual porous media, that is, fracture and matrix two systems [5].

The embedded discrete fracture model is a new model developed in recent ten years, which has both dual-medium model and discrete fracture model. It has high calculation accuracy, greatly improves simulation speed, and saves time and cost. At the same time, Lee, Moinfar, Shakib, Hajibegi, and others studied the embedded discrete fracture model and used the method of establishing the connection between fracture element and matrix element in the dual media model to explain the mass exchange between continuous media. Then, referring to the treatment method of fracture in the discrete fracture model, the fracture was discretized into shape and matrix element by matrix grid boundary. The numerical simulation results of the same fractured medium show that the embedded discrete fracture model is more accurate than the continuous medium model and the equivalent continuous medium model [6].

3. Research on numerical simulation

3.1. Establishment of numerical simulation model

| Table 1. Reservoir properties. |
|--------------------------------|
| Reservoir Dimensions (ft×ft×ft) | 1000×499.8×30 | Water Saturation (fraction) | 0.28 |
| Grid Size (NX×NY×NZ) | 145×51×3 | Initial Pressure (psi) | 3750 |
| Porosity (fraction) | 0.06 | Rock Permeability (md) | 0.001 |

To model the complex fracture network, we use the EDFM formulation. The EDFM honors the complexity of the fracture network while providing a simple model of the formation. Fig. 1 displays the model generated using EDFM. The size of the reservoir model is 1000×499.8 ft in x- and y-directions, and the reservoir thickness is 30 ft. The reservoir fluid is crude oil, and other reservoir properties are listed in Table 1. An infill grid is set every 100 ft to simulate hydraulic fracturing fractures. See Table 2 for detailed grid information.
Figure 1. The complex fracture network created by EDFM, the left is matrix model and the right is fracture model.

Table 2. Reservoir detailed grid information.

|    |    |    | 4 | 0.95 | 0.1 | 0.95 | 4 | 0.95 | 0.1 | 0.95 | 4 |
|----|----|----|---|------|-----|------|---|------|-----|------|---|
| DXV | 10*9 | 4 | 0.95 | 0.1 | 0.95 | 4 | 10*9 | 4 | 0.95 | 0.1 | 0.95 | 4 |
|    | 10*9 | 4 | 0.95 | 0.1 | 0.95 | 4 | 10*9 | 4 | 0.95 | 0.1 | 0.95 | 4 |
| DYZV | 51*9.8 |    |    |    |    |    |    |    |    |    |    |    |
| DZV | 3*10 |    |    |    |    |    |    |    |    |    |    |    |
| TOPS | 7395*10000 |    |    |    |    |    |    |    |    |    |    |    |

3.2. Analysis of influencing factors of EDFM in Complex Fractured Reservoir

To systematically study the influencing factors of complex fractured reservoir development in EDFM, the influence of reservoir type, capillary force, and fracture development degree on oil recovery rate, cumulative oil production, and recovery degree is analyzed. The influencing factors of specific model analysis are shown in Table 3.
Table 3. Scheme design of mechanism model.

| Benchmark model | Properties of actual matrix | Properties of actual fracture | Actual Capillary force |
|----------------|-----------------------------|-----------------------------|----------------------|
| Case1          | Properties of altered matrix | √                           | √                    |
| Case1-1        | Pure fractured reservoir     | √                           | √                    |
| Case2          | √                           | Properties of altered fracture | √                    |
| Case2-1        | √                           | Porous reservoir            | √                    |
| Case2-2        | √                           | Altered fracture aperture   | √                    |
| Case2-3        | √                           | Altered fracture density    | √                    |
| Case2-3×0.5    | √                           | 0.5 times of fracture density | √                      |
| Case2-3×2      | √                           | Double fracture density     | √                    |
| Case2-3×3      | √                           | Tribe fracture density      | √                    |
| Case3          | √                           | √                           | Altered Capillary force |

Remarks: √ indicates that the parameter will not be altered.

Comparing different reservoir types, it can be seen from the numerical simulation results of the EDFM mechanism model (Fig. 2) that pure fractured reservoir (case1-1) can not be developed, and the development effect of the porous reservoir (case2-1) is slightly lower than that of the porous fractured reservoir (benchmark model). The reason is that the pure fracture has no reservoir performance, so it can not be produced, and the porous reservoir has no fracture communication, so its development effect is naturally worse than that of the porous fractured reservoir.

![Figure 2](image.png)

Figure 2. Development effect analysis of different reservoir types by EDFM.

Comparing different fracture aperture, it can be seen from the numerical simulation results of the EDFM mechanism model (Fig. 3) that the production effect is slightly better than that of the benchmark model after increasing the fracture opening by 10 times (case2-2). It is analyzed that the reason is that the fracture opening has a relatively large impact on the oil production rate, but has little impact on the final recovery degree.
Compared with different fracture densities, the fracture densities are set as 0.5, 2, and 3 times the original density respectively. From the numerical simulation results of the EDFM mechanism model (Fig. 4), it can be seen that when the fracture density is adjusted to 0.5 times of the benchmark model, the impact on the development effect is very small. When it is adjusted to 2 times, the fractures can communicate with more reservoirs, and the development effect is obviously better. The fracture communication reservoir gradually reaches the maximum, and the increase of development effect decreases.

Comparing different capillary forces, it can be seen from the numerical simulation results of the EDFM mechanism model (Fig. 5) that the development effect of the benchmark model is better than that of case 3, and it is considered that the capillary force becomes resistant due to oil-wet reservoir.
4. Conclusion
1) The embedded discrete fracture model can more intuitively reflect the fracture shape and fracture attributes, and the calculation is more simple;
2) For the embedded discrete fracture model of complex fractured reservoir, the matrix characteristics, fracture properties, and capillary force of reservoir have different effects on the development effect. In the process of development effect analysis, the influence of fracture density, reservoir wettability, and other factors should be considered.

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