

Numerical Simulation of the Oil-water Distribution Law in X Block Geology by Using the STARS Mode

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Abstract: Oil reservoir numerical simulation technology is one research approach of stratum geology as well as oil reservoir development by applying mathematical methods, which establishes the simulation model of stratum oil reservoir through the oil reservoir geology model, permeability mathematical equation and numerical model. In this study, we want to seek for the oil-water distribution law as well as its characteristics in X block geology of an oil field by using the STARS model. In addition, the development history of the geology of this oil field was simulated and the development potential of this block was discussed. The results indicated that the geological model of 13 wells was extracted, which were divided into 7 simulation layer vertically with the grid system of $23 \times 9 \times 7 = 1449$. According to the single well fitting, among the 9 producing wells in the testing well block, six wells achieved good fitting, occupying 66.67%, while the rest three wells achieved poor fitting, occupying 33.33%. The prediction result that on Oct., 2026, the recovery percentage of X block was 40.95%, the oil produced was 11.09×10^4 t and the residual geological reserves were 15.99×10^4 t.

Keywords: Numerical simulation, oil reservoir geology, STARS

INTRODUCTION

Oil reservoir numerical simulation technology is one research approach of stratum geology as well as oil reservoir development by applying mathematical methods, which establishes the simulation model of stratum oil reservoir through the oil reservoir geology model, permeability mathematical equation and numerical model. Furthermore, it predicts and analyzes the space location, pore volume, oil-water distribution and pressure of stratum oil reservoir under the assistance of high-speed computer. Therefore, oil reservoir numerical simulation technology achieved wide application in geological exploration, oil production, engineering simulation and other fields (Yan *et al.*, 2009). The oil-water distribution law as well as its characteristics in X block geology of an oil field was studied and predicted by using the STARS model made by Canadian CMG Company. In addition, the development history of the geology of this oil field was simulated and the development potential of this block was discussed.

BRIEF INTRODUCTION TO STARS MODEL SOFTWARE

STARS model software, developed by a Canada Computer Simulation Software Co., Ltd, is a piece of oil

reservoir simulation software for simulating the steam flooding, thermal recovery as well as other advanced recovery processes. It is appropriate for simulating many processes for increasing the recovery ratio, such as thermal recovery, gas flooding, chemical flooding as well as microbial flooding. STARS model software is equipped with strong reaction kinetics, geomechanics and thermal equilibrium constant functions, thus making it become the most complete and flexible oil reservoir simulation software in petroleum, geology and other fields. It is characterized as:

- Parallel CMG simulator
- Encrypted dynamic grid
- Air injection
- Microbial enhanced oil recovery
- Three-dimensional geomechanics model

The main oil reservoir processes of STARS simulation are stated as follows:

- **Thermal recovery:** Steam huff and puff (Sarica *et al.*, 1997) steam flooding, solvent enhancement-steam assisted gravity flood, hot water flooding (Frederick *et al.*, 2006) thermal solvent flooding, electrical heating and water injection through temperature difference.

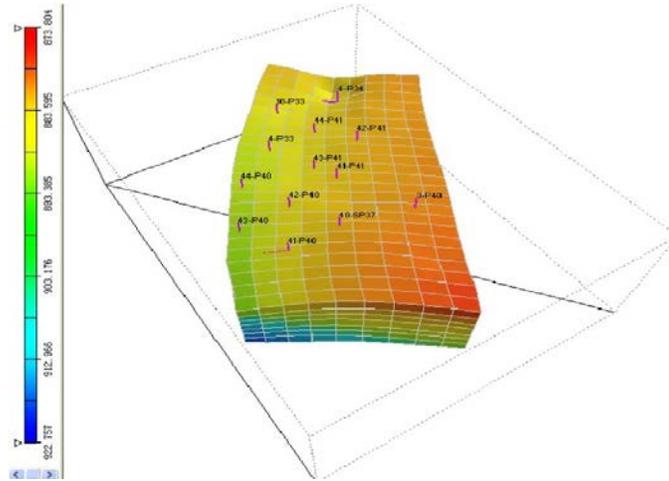
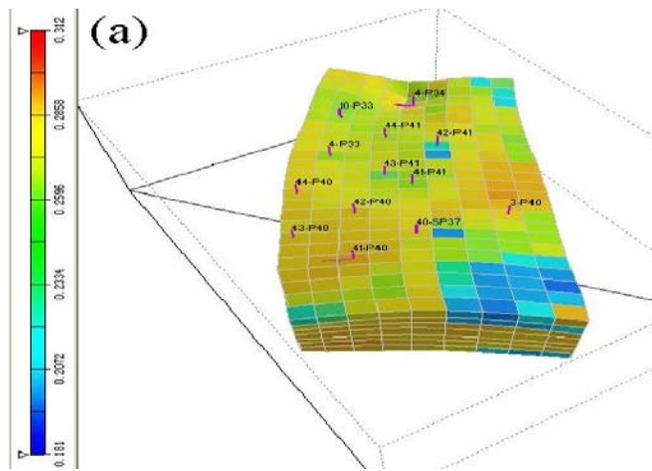
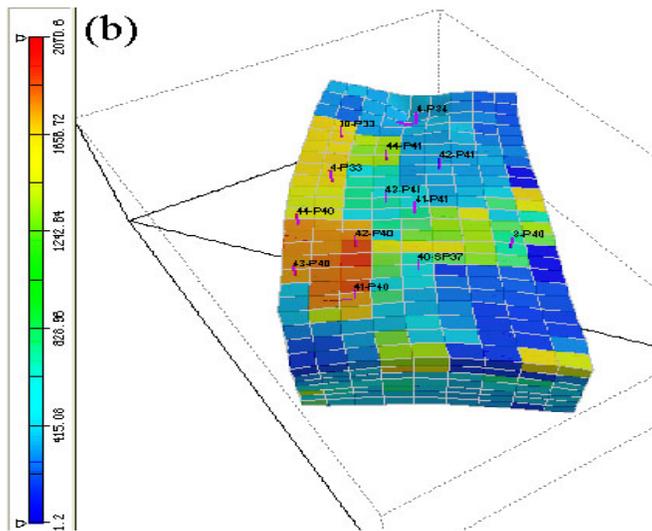


Fig. 1: Geological structure of X block



(a) Porosity model



(b) Permeability model

Fig. 2: Porosity and permeability model of X block

- **Gas flooding:** Air flooding, nitrogen flooding and CO₂ flooding.
- **Chemical flooding:** Gel, foam, emulsion and foam oil, polymer, alkali surfactant polymer flooding and oil reservoir acidification (Michael *et al.*, 2008).
- **Microbial flooding:** Microbial huff and puff, microbial profile control, microbial exogenous flooding and microbial endogenous flooding.

Considering the unique advancement of STARS model software in simulation, it was applied in this study to study and predict the oil-water distribution law and its characteristics in X block geology of an oil field.

ESTABLISHMENT OF STRATUM OIL RESERVOIR NUMERICAL SIMULATION

Four wells and 9 oil wells in the X block were selected for geology modeling and oil reservoir numerical simulation. The whole oil reservoir geology model was shown in Fig. 1. The permeability, porosity, effective thickness and saturation values of the simulating region were extracted from the whole model. Furthermore, the permeability, porosity, effective thickness and saturation values of the whole simulating region were acquired through interwell interpolation.

According to the current requirements on oil reservoir well spacing as well as refined oil reservoir simulation, the geological model of 13 wells was extracted, which were divided into 7 simulation layer vertically with the grid system of 23×9×7 = 1449. The porosity and permeability model of X block were shown in Fig. 2.

STATIC DATA APPLIED BY NUMERICAL SIMULATION

Formation pressure and temperature: The original formation pressure is 11.2 MPa. The volume coefficient of crude oil under formation pressure is 1.066 and the temperature of oil reservoir is 50°C.

High pressure physical-property parameters: The high pressure physical-property parameters in X block were presented in Table 1.

Relative permeability curve: The relative permeability curve of stratum in X block was shown in Fig. 3.

Working system of oil-water well: The method of fixed liquid quantity was applied according to the character of fitting zone, thus acquired the natural fitting by accumulating liquid output. The accumulated oil production can achieve better fitting under the condition of good water fitting.

Fitting time and step: The fitting time of X block is from Sept. 2001 to May, 2010 and the fitting time step is one month.

Table 1: Comparison on sub-regions' high pressure physical-property parameters in X block

| Item | Parameters |
|---|------------|
| Well amount (No.) | 13 |
| Original saturation pressure (MPa) | 8.570 |
| Original gas-oil ratio (m ³ /t) | 47.200 |
| Viscosity of formation oil (mPa·s) | 6.600 |
| Density of formation oil (g/cm ³) | 0.793 |
| Volume coefficient | 1.112 |
| Compressibility coefficient (10 ⁻⁴) | 8.100 |
| Average solubility coefficient of gas | 4.570 |

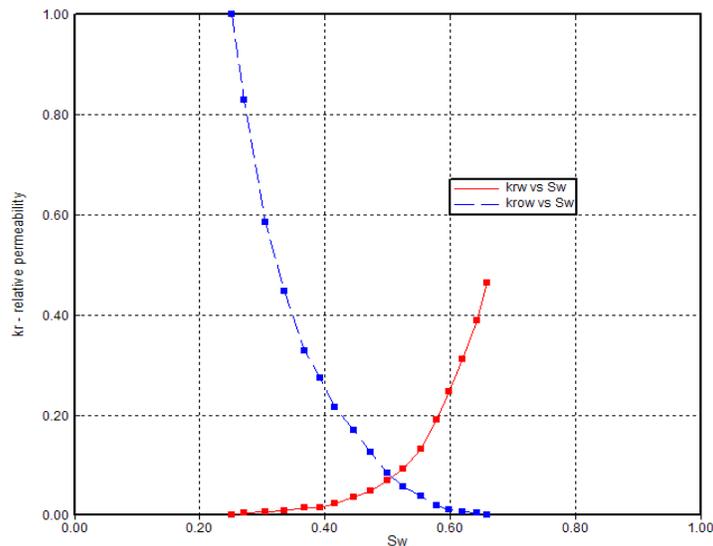


Fig. 3: Relative permeability curve of X block

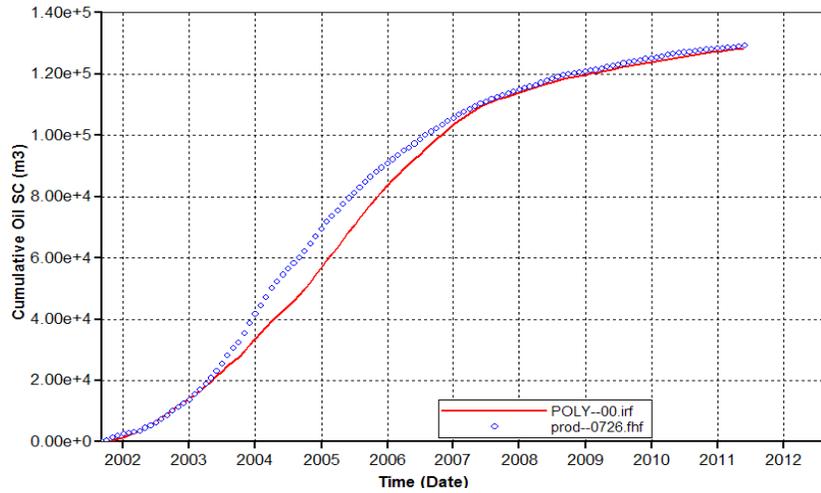


Fig. 4: Fitting curve of accumulated oil quantity in X block

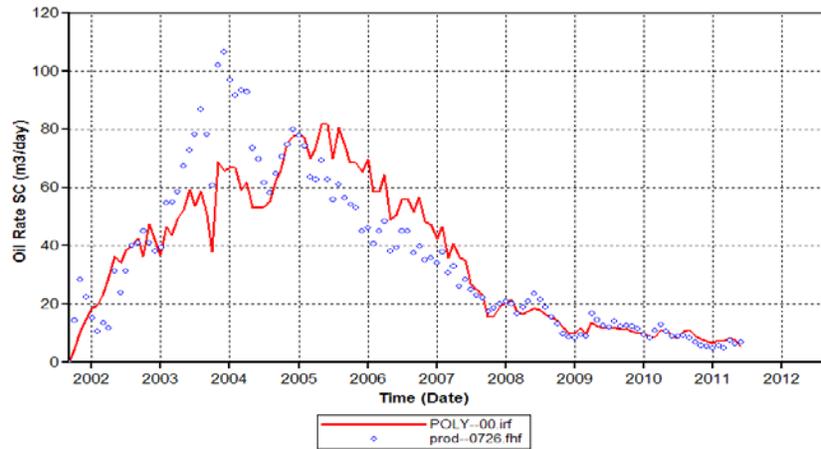


Fig. 5: Fitting curve of daily oil output in X block

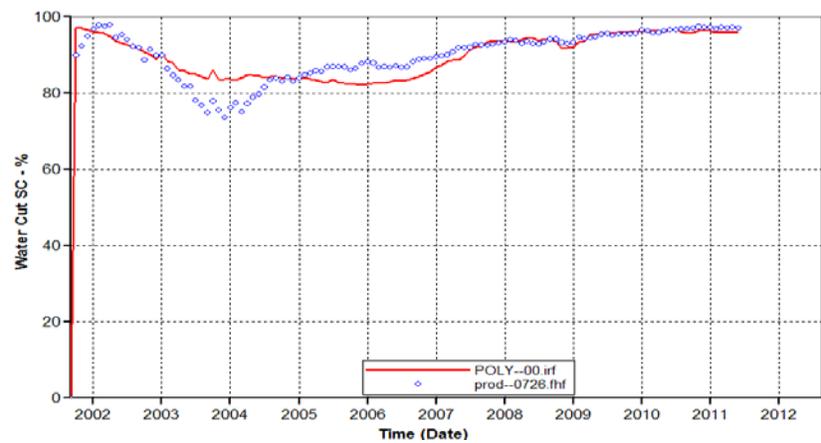


Fig. 6: Fitting curve of water content in X block

PRODUCTION HISTORY FITTING

Whole region fitting: It carried out a numerical simulation fitting on the production history of oil

reservoir in target block from its initial production to May, 2011 based on the established model. The fitting effect of oil reservoir’s production history in X block was presented in Fig. 4 to 6.

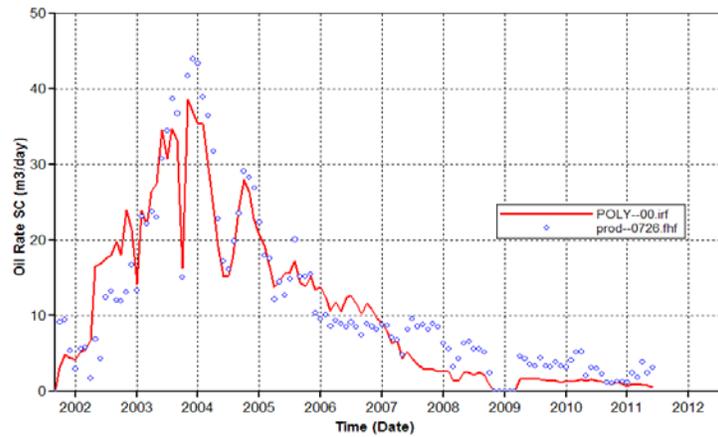


Fig. 7: Fitting curve of daily oil output of X1 well

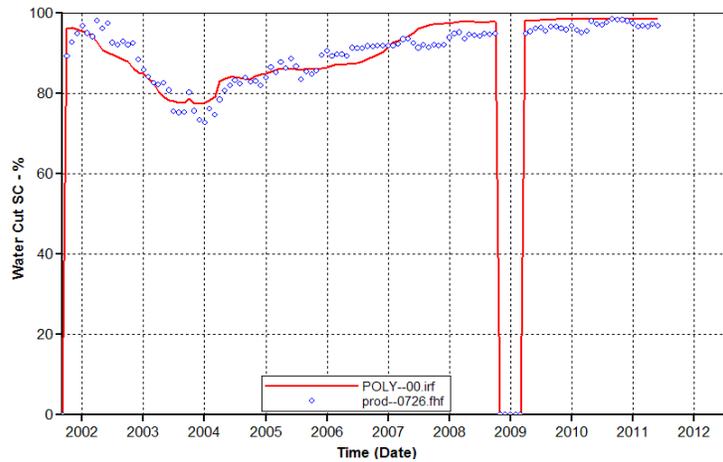


Fig. 8: Fitting curve of water content of X1 well

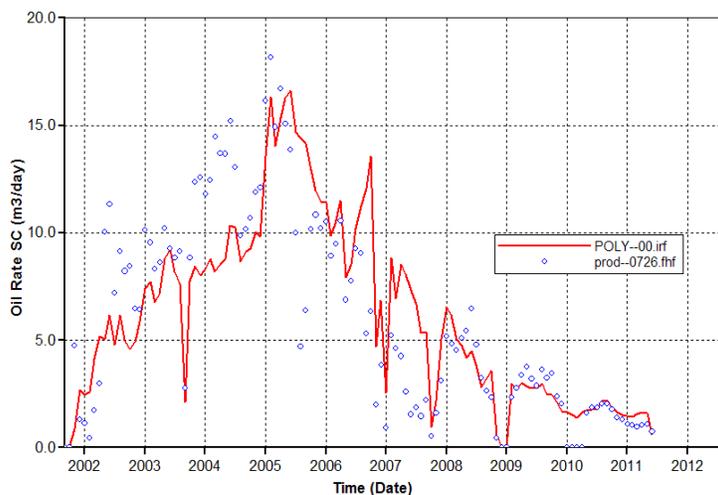


Fig. 9: Fitting curve of daily oil output of X2 well

Single well fitting: In oil reservoir simulation, single well fitting is not only the most important task, but also the core task. The quality of single well fitting

determines the simulation quality and success of prediction scheme. Therefore, oil reservoir simulation requires not only the establishment of geological model,

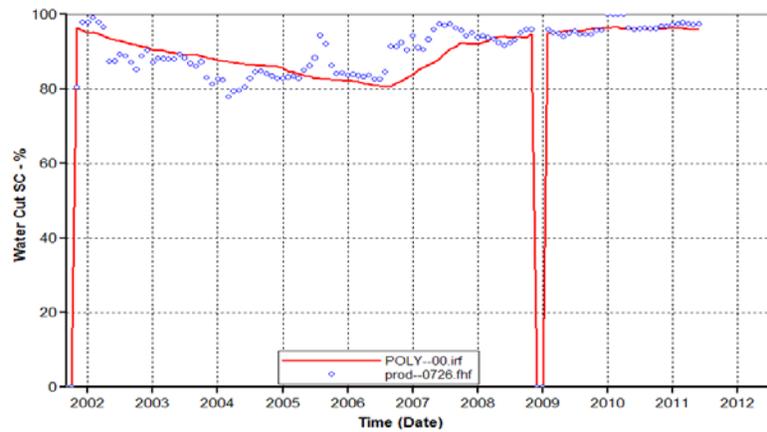


Fig. 10: Fitting curve of water content of X2 well

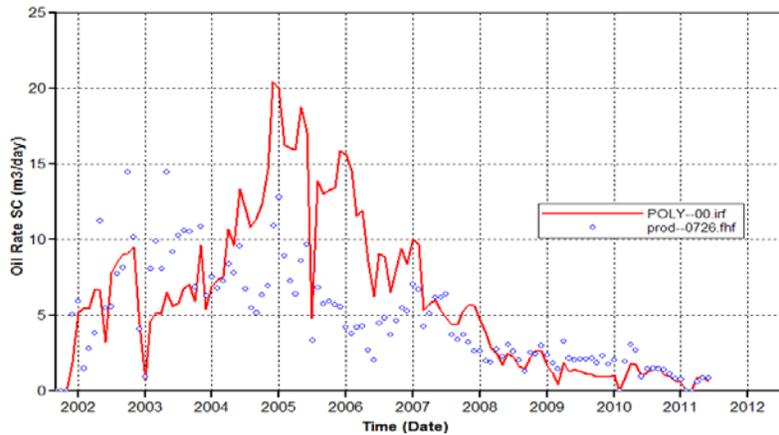


Fig. 11: Fitting curve of daily oil output of X3 well

but also the history fitting of single well. It is impossible to fit wells 100% and it is impractical for 100% well to be fitted. It is acceptable for appearing some fitting difference for some wells caused by inaccurate data and uniqueness in geological situation as well as other aspects. The fitting results of X1, X2 and X3 single well's production history in the target block was presented in Fig. 7 to 11, respectively.

Fitting result analysis: Based on the abovementioned numerical simulation curves of oil reservoir in the whole region as well as single well, the fitting data was analyzed and processed. The fitting result analysis was shown in Table 2.

Viewed from the fitting result of the whole oil reservoir, the fitting value of reserve volume, accumulated oil output and recovery percentage of the research area produced small error rate compared with actual values, indicating a good fitting on the history of oil reservoir. According to the single well fitting, among the 9 producing wells in the testing well block, six wells achieved good fitting, occupying 66.67%,

while the rest three wells achieved poor fitting, occupying 33.33%. This indicates that the water content of single well achieves good fitting effect.

MINING PREDICTION

On the basis of good oil reservoir fitting and single well fitting, the mining prediction of X block in Oct., 2026 was analyzed. The predictive analysis result of mining indexes of X block was shown in Table 3. The prediction curve of daily oil output and water content exploitation as well as the prediction curve of accumulated oil exploitation was presented in Fig. 12 and 13.

It can be known from the prediction result that on Oct., 2026, the recovery percentage of X block is 40.95%, the oil produced is 11.09×10^4 t and the residual geological reserves is 15.99×10^4 t. The recovery percentage achieved small increase amplitude till Oct., 2026 compared to that on May, 2011. However, the water content in this block increases continuously, indicating poor oil development effect in X block.

Table 2: Fitting result analysis

| Item | Actual value | Predicted value | Average error | Error rate |
|--|--------------|-----------------|---------------|------------|
| Reserve volume (10 ⁴ t) | 26.10 | 27.08 | +0.98 | +3.74 |
| Accumulated oil output (10 ⁴ t) | 10.20 | 10.17 | -0.07 | -0.20 |
| Daily oil output (t) | 6.86 | 7.63 | +0.77 | -11.22 |
| Water content (%) | 97.13 | 96.03 | -1.10 | -1.13 |
| Recovery percentage (%) | 39.23 | 37.56 | -1.67 | -4.26 |

Table 3: Predictive analysis result of mining indexes in Oct. 2026

| Oil reservoir | Geological reserves (10 ⁴ t) | Oil produced (10 ⁴ t) | Recovery percentage (%) | Residual geological reserves (10 ⁴ t) |
|---------------|---|----------------------------------|-------------------------|--|
| I | 2.11 | 0.98 | 46.38 | 1.13 |
| II | 1.86 | 0.84 | 45.14 | 1.02 |
| III | 4.05 | 2.08 | 51.36 | 1.97 |
| IV | 4.33 | 1.69 | 39.06 | 2.64 |
| V | 1.24 | 0.29 | 23.40 | 0.95 |
| VI | 6.28 | 2.30 | 36.64 | 3.98 |
| VII | 7.21 | 2.93 | 40.64 | 4.28 |
| X block | 27.08 | 11.09 | 40.95 | 15.99 |

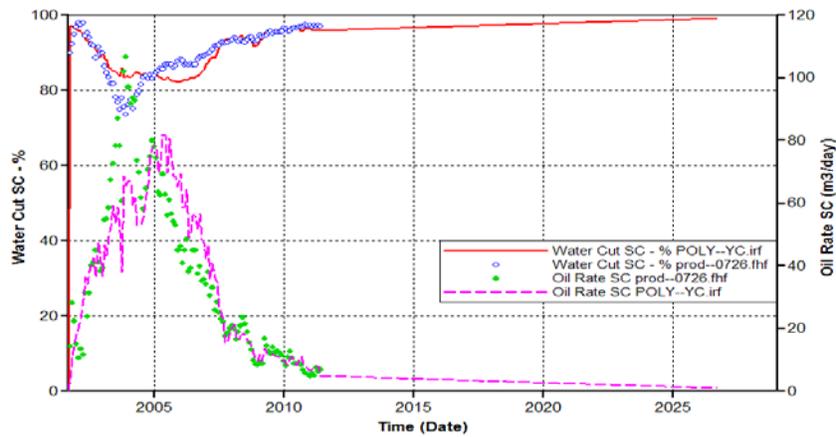


Fig. 12: Prediction curve daily oil output and water content exploitation in X block

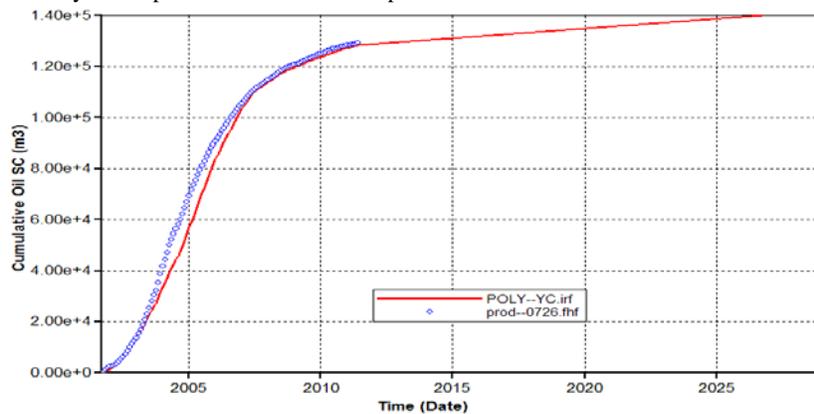


Fig. 13: Prediction curve of accumulated oil exploitation in X block

CONCLUSION

In this study, the oil-water distribution law as well as its characteristics in X block geology of an oil field was studied and predicted by using the STARS model. In addition, the development history of the geology of this oil field was simulated and the development potential of this block was discussed. The conclusions

are got from the theory analysis and numerical simulation in this study as following:

- The geological model of 13 wells was extracted, which were divided into 7 simulation layer vertically with the grid system of $23 \times 9 \times 7 = 1449$.
- According to the single well fitting, among the 9 producing wells in the testing well block, six wells

achieved good fitting, occupying 66.67%, while the rest three wells achieved poor fitting, occupying 33.33%.

- The prediction result that on Oct., 2026, the recovery percentage of X block was 40.95%, the oil produced was 11.09×10^4 t and the residual geological reserves were 15.99×10^4 t. The water content in this block increased continuously, indicating poor oil development effect in X block.

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