SIS Global Forum 2019

Innovation and Application of Numerical Simulation Technology for Bohai Heavy Oil Thermal Recovery

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September 2019

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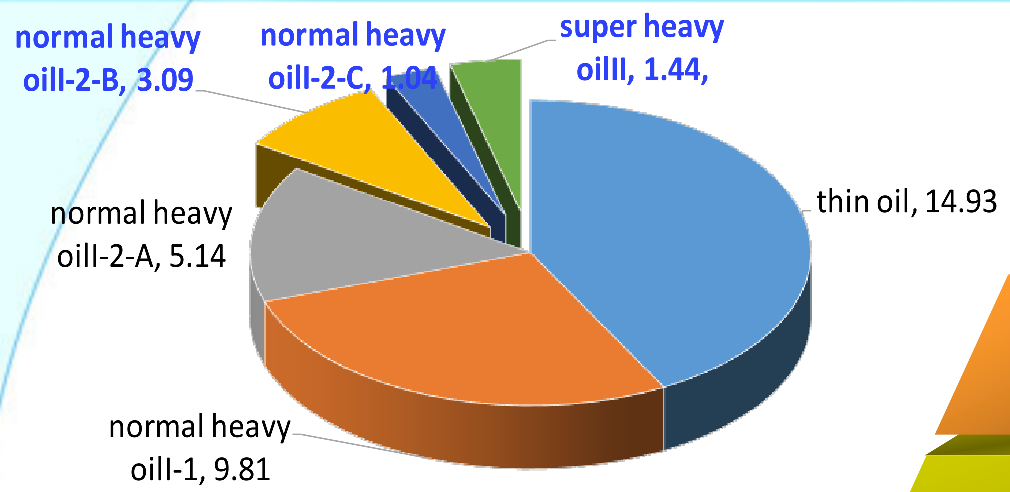
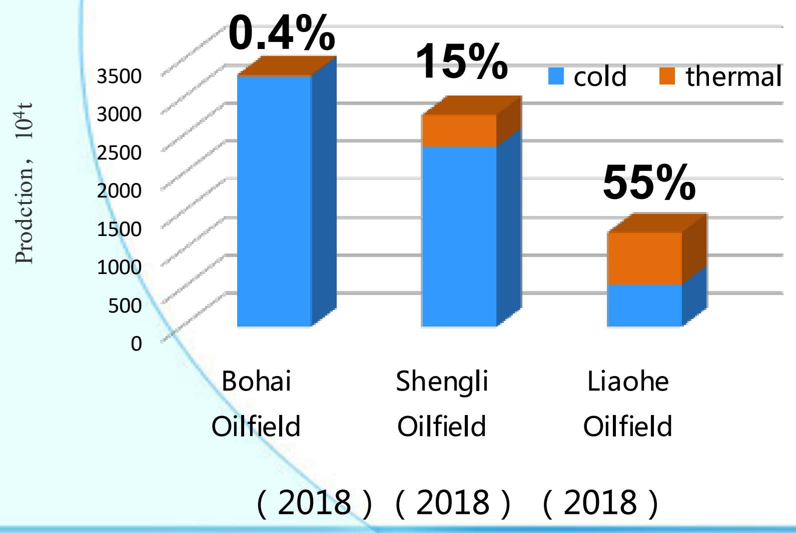
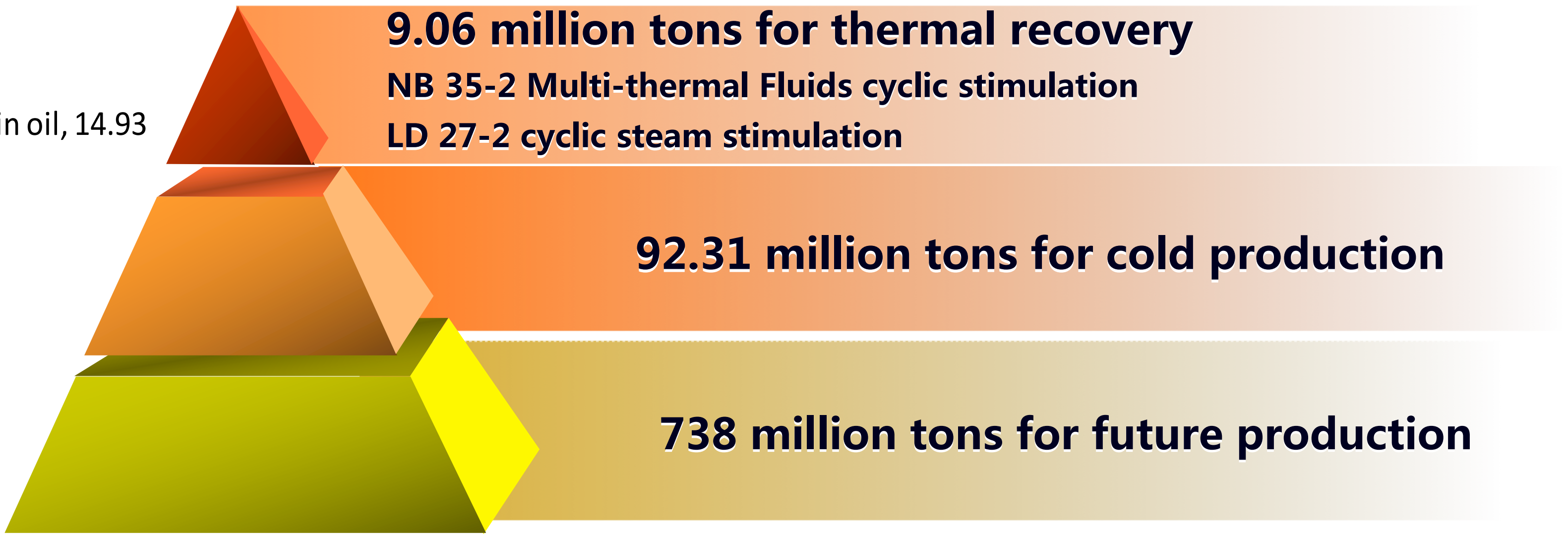
- The purpose and significance of Bohai heavy oil thermal recovery
- Thermal numerical simulation technology innovation
- The application effect

First, the great potential of Bohai heavy oil thermal recovery





Bohai special heavy oil reserves development situation



- The Bohai oilfield is rich in heavy oil reserves. The proved reserves are 560 million tons, and the 3P geological reserves of crude oil viscosity greater than 350cp are 840 million tons;
- The development experience of NB35-2 and LD27-2 oilfield shows that the development of special heavy oil cold production is poor, and it is necessary to adopt thermal recovery ;
- In Shengli and Liaohe oilfield , the thermal recovery production accounts for 15% to 55% of total production, so we has a large potential for thermal recovery.

Second, numerical simulation technology is essential for heavy oil thermal recovery

Offshore heavy oil thermal recovery characteristics

Large well spacing

the thermal recovery well spacing are 3 to 4 times of onshore oil fields

Special development method

first implement the Multi-thermal Fluids cyclic stimulation development test

Heat injection equipment limit

At present, the equipment can only provide heat for 1~2 wells at the same time.

Thermal development

Pressure field

Saturation field

+

Temperature field

Viscosity field

Thermal property field

On the mechanism of Thermal recovery, thermal development needs to consider temperature field, viscosity field, thermal property field, etc. Conventional water injection development can be combined with reservoir engineering method and numerical simulation method. Due to multi-field coupling，numerical simulation has become an important predicting method in thermal recovery.

Third, the application of Eclipse thermal production module

The forecasting capacity of heavy oil thermal development has been greatly improved, and five oilfields thermal recovery plan have been reviewed.

QHD33-1S → PL9-1 → PL15-2 → LD16-1 → LD 21-2

- Steam stimulation → Multi-thermal fluid
- Local thermal recovery → Overall thermal recovery
- Single reservoir type → Multiple reservoir types

- The application of numerical simulation technology for different thermal recovery methods and scales in different reservoir types has been realized.

Four,problems

(1) The biggest difference between thermal recovery simulation and conventional water flooding simulation is the description of "heat". How much influence does each thermal property parameter have on development forecast? Is there any change in the characteristics of thermal recovery of heavy oil offshore?

(2) How to choose the development method of offshore heavy oil thermal recovery?

(3) How to improve the precision of the prediction results for thermal recovery forecast?

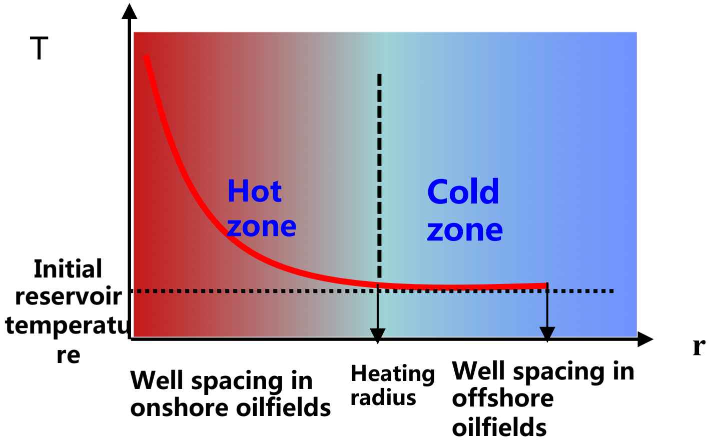
Porous media flow characteristics? How to choose the thermal method?

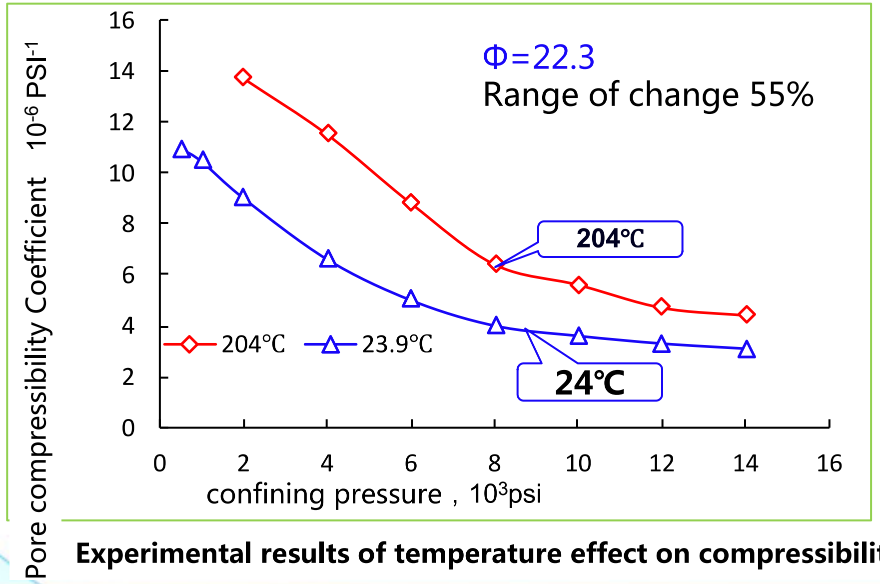
Contents

First, the rock compressibility coefficient temperature sensitivity

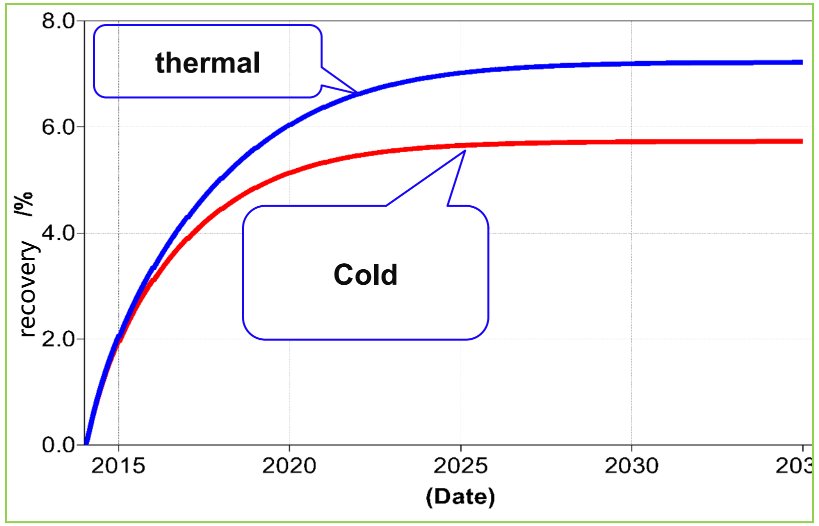
Problem1 : the difference in the development effect of hot and cold production under large well spacing is small.

- The thermal production well spacing in the onshore oilfield is small, and the developing radius is in the hot zone;
- The offshore thermal production well spacing is large, and the developing radius is divided into hot zone and cold zone;
- Experiments show that the higher the temperature, the larger the pore compressibility;
- With a constant compressibility factor, the difference in recovery between thermal recovery and depletion is small.





Experimental results of temperature effect on compressibility coefficient

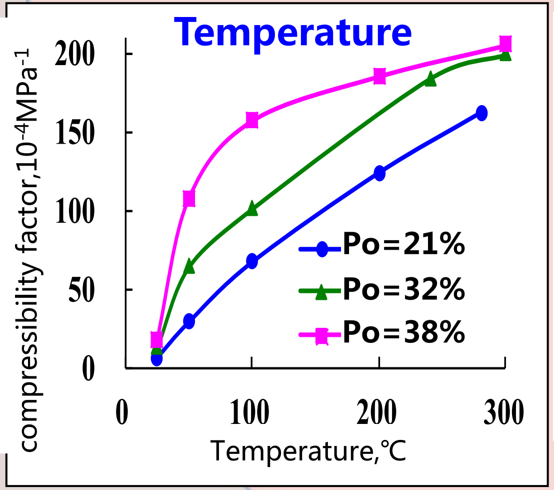


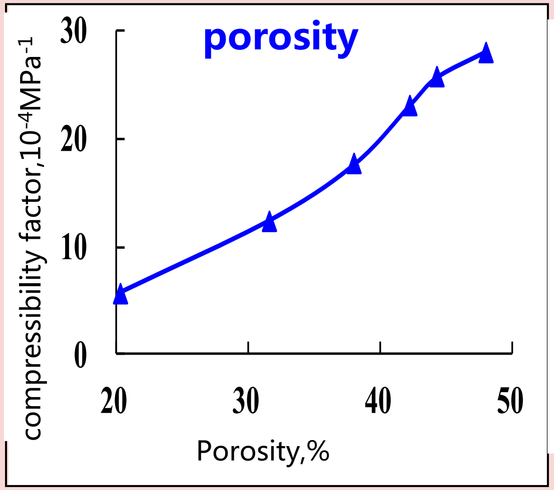
Cold and Heat Recovery at Constant compressibility Coefficient

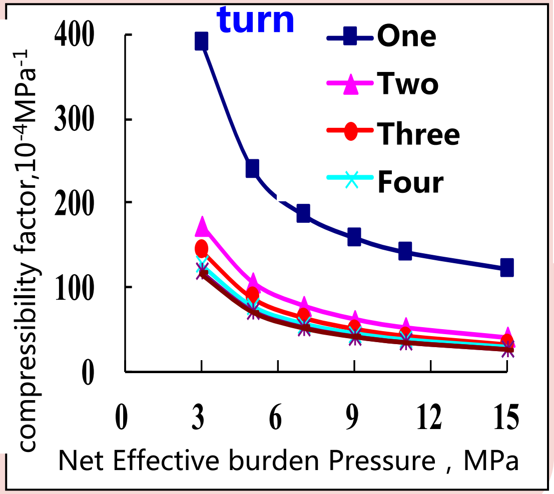
First, the rock compressibility coefficient temperature sensitivity

The experiment shows that the compressibility coefficient is also affected by many factors such as the number of cycles of steam stimulation, porosity, temperature and pressure. A dynamic compressibility coefficient technique considering reservoir physical properties is proposed firstly.

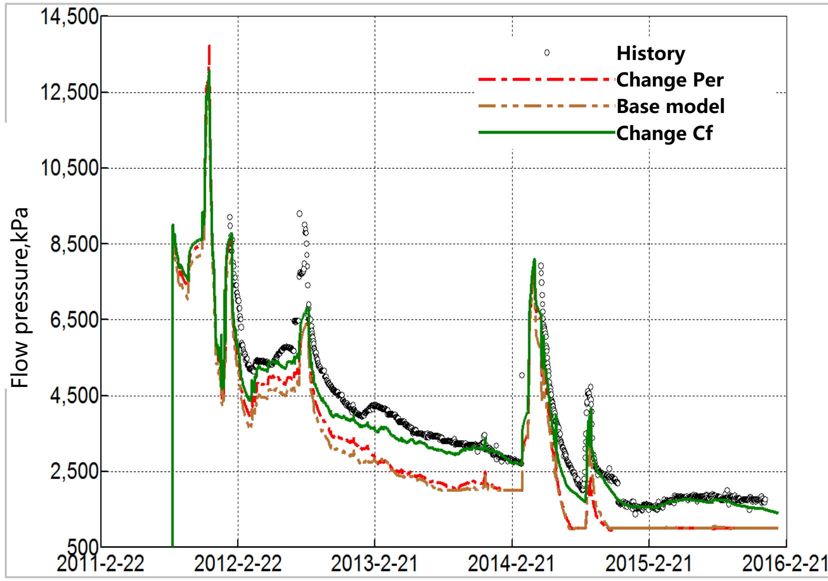
With the increase of temperature and porosity, rock compressibility coefficient increases. Rock compressibility coefficient decreases with the increase of huff and puff rounds.





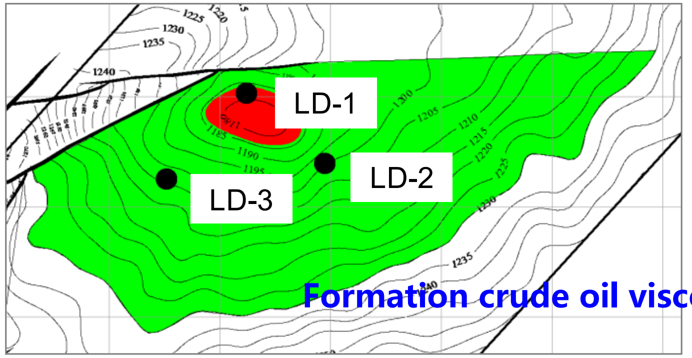


the prediction accuracy is greatly improved, which is consistent with the actual.



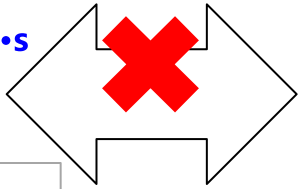
Second, special / super heavy oil start-up pressure equivalent simulation

Problem2: the actual cold production of the super heavy oil field has no production, but the oil can be produced in numerical simulation.



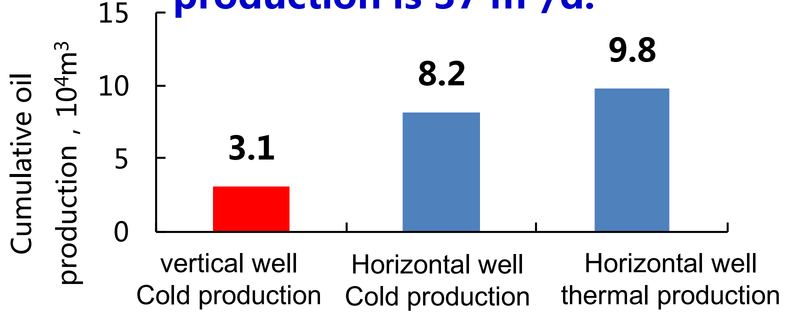
LD16-1 Oilfield

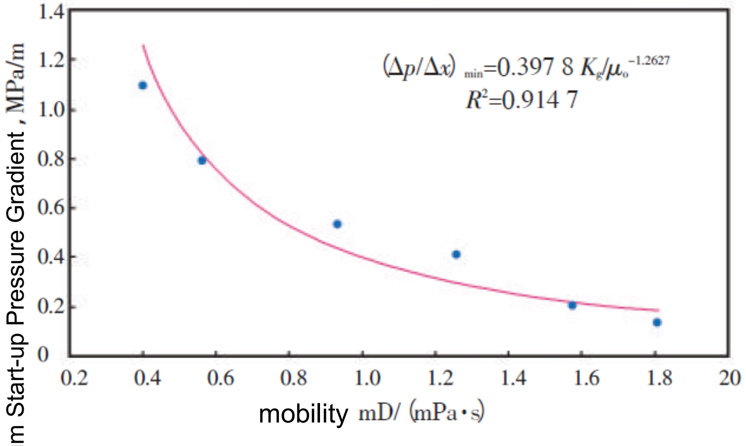
Formation crude oil viscosity: 15000mPa•s



Test overview:
In February 1993, the LD-1 well was tested and no production was obtained.
In October 2008, the LD-2 well was tested and no production was obtained.
From October to November 2013, LD-3 well test, also no production.

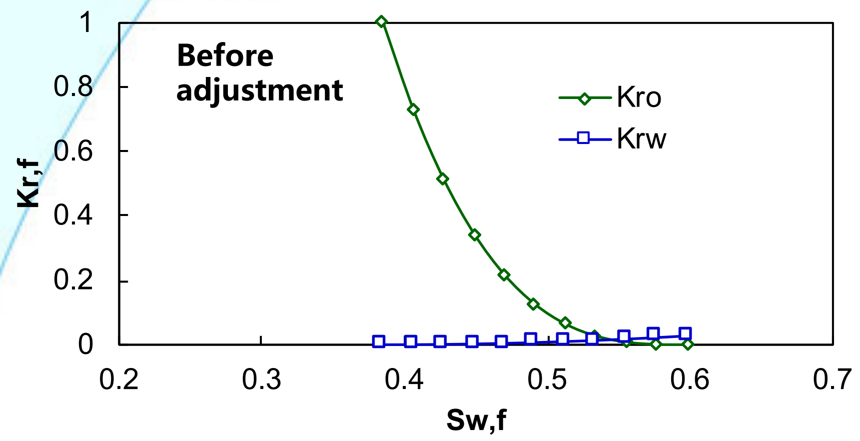
In the model, the initial production of cold production is 37 m³/d.

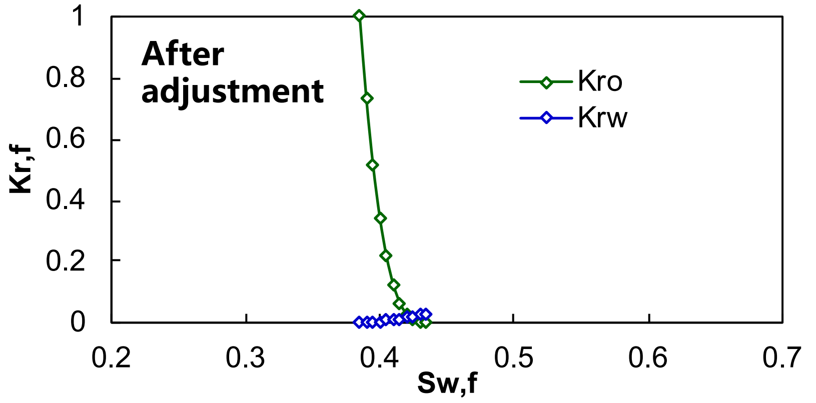




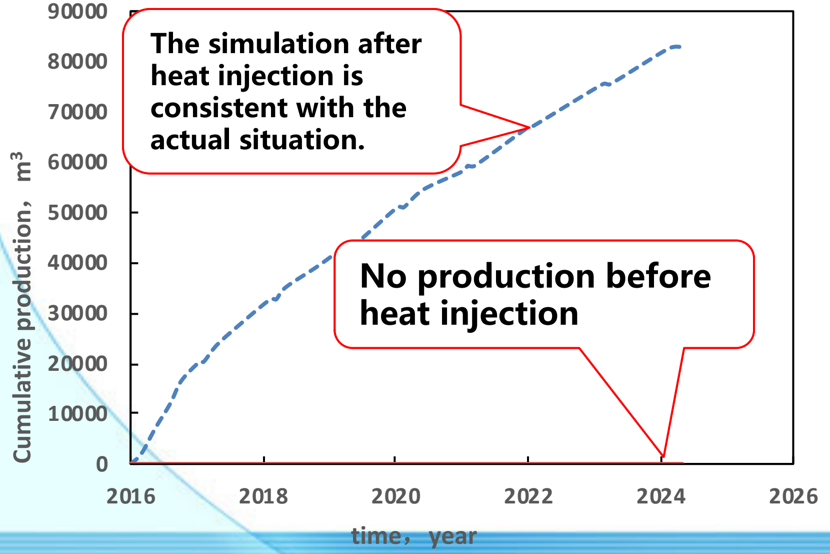
This is mainly due to the fact that the start-up pressure at different temperatures is not taken into account in the model.

Second, special / super heavy oil start-up pressure equivalent simulation





Application effect



The low temperature relative permeability curve is changed, so that the production is zero under the initial temperature. The high temperature relative permeability curve keeps the same. The simulation results after adjustment are consistent with the actual thermal recovery test, which greatly improving the simulation accuracy.

Third, the rapid decision-making technology of cyclic stimulation

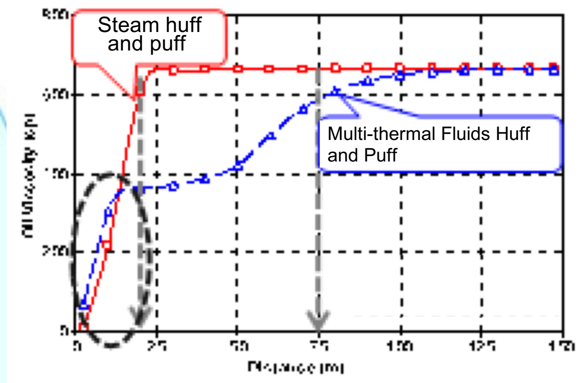
Problem3 : the Bohai oilfield has conducted multi-thermal fluid cyclic stimulation and CSS tests.

How to quickly choose the development method?

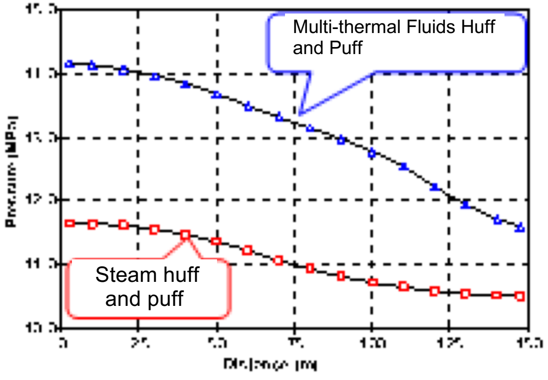
- **The heat enthalpy value of steam stimulation is significantly higher than that of multi-fluid, and the viscosity reduction effect is better than that of multiple heat fluid. The multi-fluid has better pressure holding effect;**
- **We studied the effects of oil layer thickness, crude oil viscosity, permeability, Kv/Kh value and rhythm on the cyclic stimulation development. It is believed that the viscosity of the crude oil and the thickness of the oil layer are the primary factors affecting the development effect.**
- **Considering the combination of viscosity and thickness changes, numerical simulations are carried out to draw different patterns of throughput.**

	Steam stimulation	Multiple thermal fluid throughput
Advantage	The thermal enthalpy value is significantly higher than that of the multi-component thermal fluid, and the heating and viscosity reduction effect near the near well is better than the multi-component thermal fluid.	Expand heat wave area, increase energy and maintain pressure, increase elastic energy

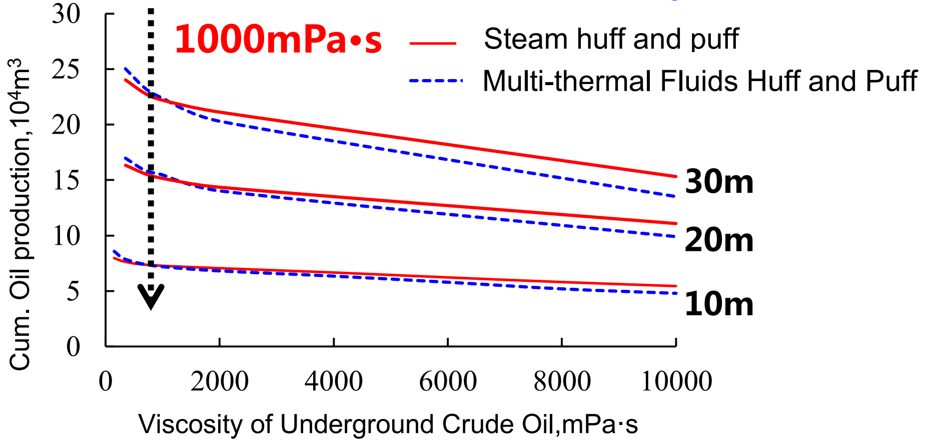
viscosity distribution



pressure distribution



Fast decision making with different cyclic methods



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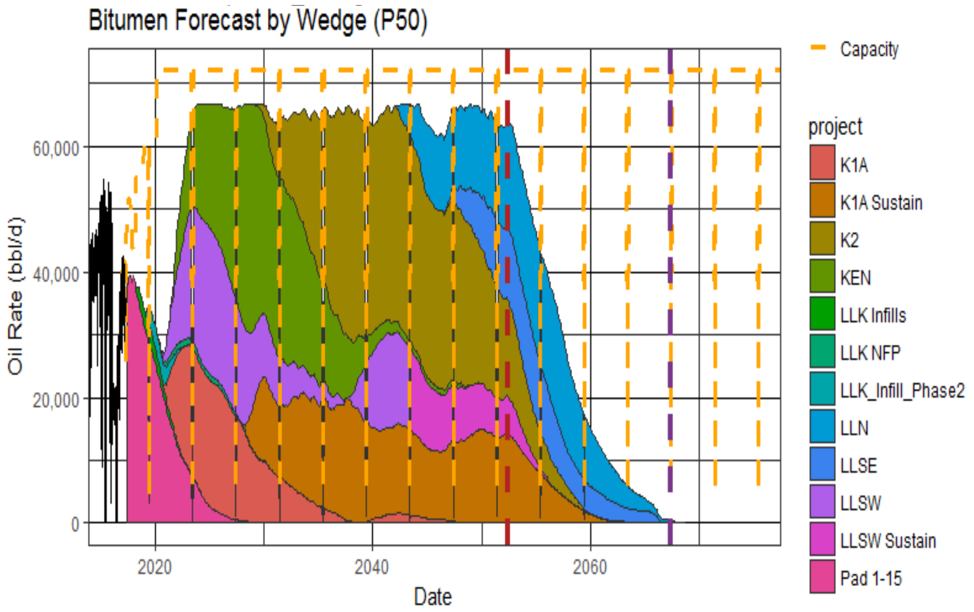
Last,The application in CNOOC oilfield

- The technique have been approved by Tianjin branch company and applied in the preliminary project of heavy oil thermal production such as LD5-2N.
- The technical achievements have been successfully applied in oilfields such as LD21-2 and JZ23-2, supported domestic heavy oil thermal recovery.
- Improve the numerical simulation accuracy of the Canadian oil sands, and help CNOOC's overseas asset development to reduce costs and increase efficiency.

status	Undeveloped heavy oil field	Exploring geological reserves
In construction	LD21-2	30000
Base	LD5-2N	
Feasibility study	JZ23-2	
	KL9-5/6	
	PL9-1	
	PL15-2	
	LD16-1	
	QHD33-1S	



Thanks！

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