

IOR AND EOR – CHANCES FOR INCREASE OF OIL PRODUCTION AND RECOVERIES IN EXISTING, MATURE RESERVOIRS

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Abstract

After the application of conventional oil extraction techniques, about 2/3 of discovered reserves still remain to be produced. In view of high probability for oil presence and oil price increases, investments in research of possibilities for higher recoveries and higher production with application of appropriate IOR and EOR methods are justified, naturally under economic conditions.

Sažetak

Nakon primjene konvencionalnih metoda iskorištavanja naftnih ležišta, u njima ostaju nepridobive 2/3 od otkrivenih količina. U okolnostima velike vjerojatnosti njihova postojanja i visoke cijene nafte, opravdana su ulaganja u istraživanja mogućnosti povećanja njihova iscrpka i proizvodnje u svim fazama iskorištavanja ležišta primjenom IOR postupaka (poboljšanih metoda iskorištavanja) i EOR metoda (metoda povećanja iscrpka), naravno pod profitabilnim uvjetima.

Introduction

Let us assume the position of owner or at least oil company director, whose main task is renewal of reserves, and whose business success is measured by reserve replacement ratio.

New recoverable reserves of oil and gas can be obtained in the following manner ⁽³⁾:

- Discovery of new reservoirs as a consequence of continuous pursuit of basic activity – exploration of domestic and foreign exploration areas;

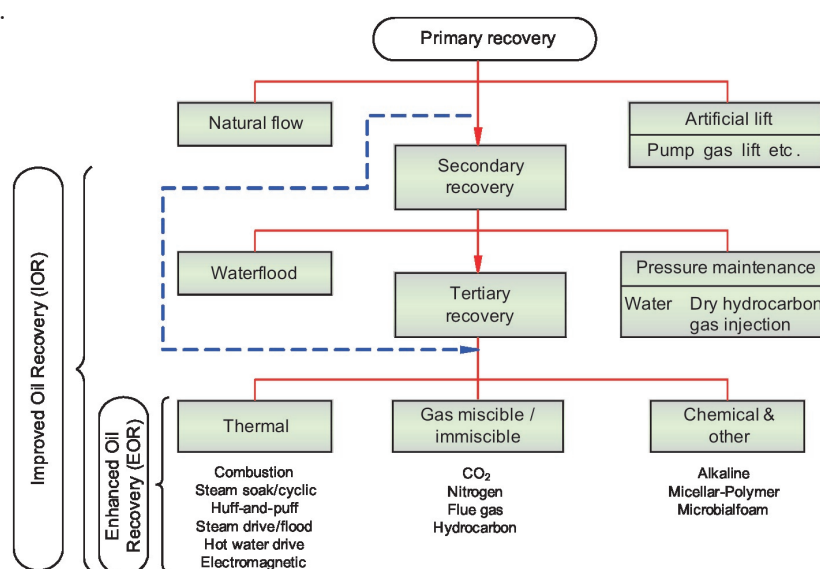


Figure 1 Proposed definitions of the EOR and IOR terms⁽⁸⁾

Slika 1. Predložena definicija EOR metoda i IOR postupaka⁽⁸⁾

- Improvement of reservoir models by application of new geophysical methods, state-of-the-art interpretation techniques and reinterpretation of all available data in combination with data obtained during reservoir exploitation (produced quantities of fluid and change in reservoir pressure);
 - Application of EOR methods in reservoirs with inefficient displacement drives:
 - in the secondary stage of oil displacement by physical activity – injection of water or gas into the reservoir;
 - in the tertiary stage by freeing oil trapped in pore space after secondary stage by thermal or chemical activity – through application of EOR processes;
 - Introduction of new technologies on existing fields: infill drilling, recompletions, fracturing, drilling of horizontal wells and sidetracking from existing holes to activate less permeable parts of the reservoir and catch the by-passed oil by IOR processes or reservoir management.
1. EOR methods, also known as tertiary recovery methods, mobilize oil trapped by capillary and viscosity forces during reservoir water flooding in the secondary stage. Oil is freed by chemical and thermal activity, by injecting solvents and chemicals and heating of the reservoir.
 2. IOR processes are applied mainly in the secondary and tertiary reservoir depletion stage to increase reservoir sweep efficiency coefficients by displacing fluids – looking for trapped oil by denser well spacing pattern, drilling of horizontal wells and sidetracking from existing holes, fracturing and use of polymers to improve fluid mobility ratio.

Exploration of domestic and foreign areas

Common problem of Central European oil companies is high degree of exploration of domestic exploration

areas, without great probability for discovery of larger quantities of hydrocarbons. The situation in Croatia is a good example⁽¹⁾.

The territory of Croatia is divided in three exploration areas: the Pannonian basin, the Dinarides and the Adriatic offshore. A total of 332,6 million m³ of oil and condensate and 129,8 billion m³ of natural gas were discovered so far from 34 oil fields and 20 gas and gas-condensate fields. All oil was discovered in the Pannonian basin, and most of gas comes from the Pannonian basin and partly from the Adriatic offshore.

Despite great efforts, there were no major discoveries in the Pannonian basin in the last 20 years. We have to answer two important questions:

- Is the Pannonian basin sufficiently explored, and
- Is there a probability for discovery of new, larger quantities of hydrocarbons?

According to evaluations made within the framework of hydrocarbon potential investigation studies for the Croatian part of the Pannonian basin, two to four times more hydrocarbons were generated than they are discovered so far, which means that between 900 and 1 800 million m³ of undiscovered quantities of oil equivalent could still be present in the subsurface. However, in spite of numerous seismic surveys and drilling of 850 exploratory and 2 780 production wells, these assumptions have not been confirmed.

Evaluation of possible discoveries of hydrocarbons were made applying the *Arps-Roberts* method. based on areas and reserves of hydrocarbons in already discovered fields. The data from 52 oil, gas and gas-condensate fields were processed.

Results of evaluations are shown in Table 1. According to analysis results, exploration targets were small and probability for discovery was low, but they could still be attractive due to available infrastructure for treatment and transportation of hydrocarbons.

Table 1 Calculation of ultimate number of fields in each size class

Tablica 1. Izračunati konačni broj polja po klasama površina i zaliha ugljikovodika

Class	Number of Fields	Number of Fields Smoothed	Total Area of Fields (km ²)	Average Production Area (km ²)	Original Oil in Place (1000 m ³)	Estimated Number of Fields	Total Productive Area (km ²)	Original Oil in Place (1000 m ³)
	K_1	K_2	A_1	A_2	R_{oil}	K_{oil}	$K_{oil} \cdot A_1$	$K_{oil} \cdot R_{oil}$
1	4	2.78	1.19	0.43	1129	56.6	24.2	63883
2	7	6.61	6.90	1.04	1128	56.9	59.5	64227
3	10	10.89	23.92	2.20	2406	47.7	104.8	114781
4	13	12.48	55.27	4.43	4091	30.7	135.8	125440
5	11	9.94	97.56	9.82	14865	14.5	142.2	215314
6	5	5.50	82.71	15.04	25677	6.6	99.6	169976
7	2	2.11	90.11	42.63	30214	2.1	90.7	64294
Total	52	50.31	357.66	7.11	440612	215.1	656.7	817914

These results point out the only possible solution - exploration of insufficiently explored domestic exploration areas, in this case primarily the Dinarides, and foreign exploration areas. Will it be independently or jointly with other companies depends on the financial strength and company policy.

EOR methods

High depletion of oil reservoirs discovered several decades ago is attributable to high exploration of the larger part of the European continent. Conventional enhanced oil recovery methods, such as water flooding and gas injection, were applied successfully in this area. We know about experiments with thermal processes in Romania and Hungary and displacement of oil with CO₂ was attempted in Austria, Hungary, etc.

According to natural depletion drives, recovery for all discovered oil reserves in Croatia was only about 25 %⁽²⁾. Recoveries were the smallest in the reservoirs with the largest reserves. Afterwards, following the world practice and effectiveness of natural water drive, reservoir pressure maintenance method by injection of water into 8 reservoirs/fields and gas injection into one field has been applied since 1972. Water flooding is applied on 58 % of all discovered reserves. By this processes recoverable oil reserves were increased by approx. 30 million m³, and recovery from earlier mentioned 25,00 to 34,45 %.

By the end of 2002 total production of oil at recovery of 32,5 % reached 102,0 million m³ and remaining recoverable oil quantities are estimated at about 7,0 million m³. The status of reserves, in percentages, is presented in Table 2.

Table 2 Oil recovery rates and oil reservoir depletion methods, %

Tablica 2. Iscrpci nafte u raznim fazama iskorištavanja ležišta

Recoverable	34,45
- recovered	32,50
-primary recovery	50,91
-secondary recovery	49,09
-tertiary recovery	0,00
- remainder	1,90
Unrecoverable	65,55

In spite of such good results achieved by water flooding, oil production has been constantly decreasing since 1981. The question is how to stop such production decrease. The solution lies in emerging of an idea how to recover a part of remaining 205,2 million m³ of currently unrecoverable oil reserves.

The idea how to increase oil recovery from water ooded reservoirs in tertiary stage of production has been developing for a long time. The solution was found in CO₂ injection as the most efficient method, since in addition to its positive characteristics and proved efficiency, CO₂ is available in high quantities, at present discharged into the atmosphere. Possible application is expected in the near future, primarily on Ivanić and Žutica fields. Numerous laboratory analyses, studies and numeric simulations were carried out and they indicate possibility for recovery increase by 12 to 14 % under miscibility or near miscibility conditions.

Economic valuation for one of the projects⁽⁶⁾ was done for different variants:

- Variant A – extension of existing water flooding system
- Variant B – oil displacement with CO₂.

with oil price at 20 \$/bbl (125,8 \$/m³) and gas price at 0,12 \$/m³ and discounted rate of 10 %. The obtained results are as follows:

- Positive project duration:
variant A – 10 years
variant B – 23 years or more
- Expected future total production:

Variant	Oil tons	Gas 10 ³ m ³
A	1 538 295	445 018
B	5 462 283	1 302 620
Difference	3 923 988	866 602

- Net present value:
variant A – 32 264 000 \$
variant B – 50 144 000 \$
- Payout period:
variant A - 2 years
variant B – 12 years
- value of investments and production costs per unit of product, \$/BOE

Variant	Capex	Opex	Total
A	1,12	15,01	16,13
B	2,19	9,81	12,00

After application in these fields, the method could be extended to other fields in the same region.

IOR processes

Good results should also be expected from application of IOR processes, regardless of the manner of realization. The study on possibilities to search for bypassed oil in highly water flooded part of the reservoir on Šandrovac⁽⁷⁾ field was also prepared.

Analysis of sedimentation conditions, effective thicknesses, injected water flood front shifting as well as achieved recoveries from well drainage areas, helped locate the areas for 10 side-tracked holes and one horizontal well. They would double the quantity of oil in comparison with current production, with recovery rate increase by 5,8 %. Planned investments amount to approx. 500 000 \$ per well. With oil price at 16 \$/bbl and discounted rate of 10 %, net present value of 15,1 million \$ was obtained, while payout time was one year and 10 months.

All such projects are burdened with high water cut in produced fluid. Hopefully, the problem will be solved in the near future. At a time when produced quantities of oil are accompanied by twice as large quantities of water, the problem is of global proportions and its solution would considerably reduce production costs.

Conclusion

These considerations point out the need for exploration in new promising areas and applying of IOR processes and EOR methods on existing fields.

Produced indigenous oil is more valuable for domestic economy than imported oil and oil companies, scientists and experts from this sphere of activity face a permanent task how to maintain production levels and increase recovery from existing old fields in a profitable manner.

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