Innovative Applications For Stranded Barrels of Oil

Conference

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EOR POTENTIAL OF OIL FIELDS IN CROATIA

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EOR potential of oil fields in Croatia

- many reservoir and reservoir fluid properties = great diversity of oil reservoirs
  - not all oil reservoirs are suitable for EOR
  - not every EOR method is applicable to a certain oil reservoir

inventory of all significant reservoir and fluid properties

promising fields / reservoirs suitable for EOR implementation

published empirical criteria for applicability of EOR methods

EOR potential of oil fields in Croatia

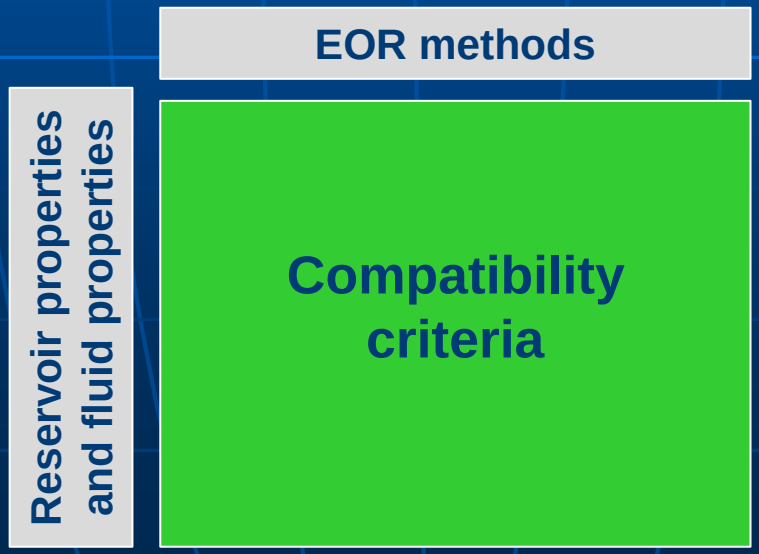
1. Current EOR experiences in Croatia
2. EOR Screening criteria
3. Screening of Croatian fields
4. Conclusion

Current EOR experiences in Croatia

- 1978 - 1991: laboratory research of CO_2 usage for oil displacement
- WAG optimal for Ivanić and Žutica oil fields
- Ivanić CO_2 pilot project:
    - 2001 - 2003: represurisation by injecting water
    - 2003 – 2006: CO_2 injection
- 2007 - 2014: full field project design and construction of surface facilities on Ivanić and Žutica
- 2014: Testing phase of full field CO_2 injection at Ivanić
- **2014 - 2037: prediction that 3,4 million tons of incremental oil will be produced from the Ivanić and Žutica oil fields**

EOR screening criteria

- Screening criteria: Taber et al, 1996
    - empirical
    - based on real world EOR projects
- criteria supplemented with additional reservoir & fluid properties (13 total) and aditional EOR methods (11 total)



EOR screening criteria

Favorable reservoir properties and reservoir characteristics	EOR methods										
	Nitrogen and flue gas miscible flooding	Hydrocarbon miscible flooding	CO_2 miscible flooding	Immiscible gas injection	Micellar polymer, Alkaline-surfactant-polymer and alkaline flooding	Polymer flooding	In situ combustion	Cyclic steam stimulation (huff and puff)	Steam flooding	SAGD (steam assisted gravity drainage)	MEOR (microbial enhanced oil recovery)
Stock tank oil density (kg/m^3)	< 850; average 790	< 916; average 820	< 922; average 845	< 986; average 918	< 934; average 850	< 966; average 896	< 1 000; average 959	< 1014; average 968	< 1014; average 968	< 1014; average 968	< 950; average 875
Current oil viscosity In situ (mPa*s)	< 0,4; average 0,2	< 3; average 0,5	< 10; average 1,5	< 600; average 65	< 35; average 13	< 150; >10	< 5 000; average 1 200	< 200 000; average 4 700	< 200 000; average 4 700	< 200 000; average 4 700	< 50
Oil composition	High percent of C_1-C_7	High percent of C_2-C_7	High percent of C_5-C_{12}	Not critical	Some organic acids	Not critical	High percent of C_{10}+; some asphaltic components	Not critical	Not critical	Not critical	Not critical
Current oil saturation (% pore volume)	> 40; average 78	> 30; average 71	> 30; average 46	> 45; average 70	> 35; average 53	> 50; average 64	> 50; average 67	> 40; average 66	> 40; average 66	> 40; average 66	> 50; average 60
Formation type	Sandstone or carbonate	Sandstone or carbonate	Sandstone or carbonate	Not critical	Sandstone	Sandstone	Sandstone, sand or carbonate	Sandstone or sand	Sandstone or sand	Sandstone or sand	Sandstone
Net pay (m)	< 3, unless dipping reservoir	< 3, unless dipping reservoir	Wide range	Not critical	Not critical	Not critical	> 3	> 6	> 6	> 6	Not critical
Average absolute permeability (mD)	Not critical	Not critical	Not critical	Not critical	> 10; average 450	> 10; average 800	> 50	> 100; average 2 700	> 100; average 2 700	> 100; average 2 700	> 75; average 190
Average porosity (%)	> 11; average 18	> 11; average 18	> 11; average 18	> 11; average 20	> 15; average 20	> 15; average 20	> 15	> 20	> 20	> 20	> 12; average 19
Reservoir depth (m)	> 1830	> 1220	> 760	> 550	< 2750; average 1000	< 2750	< 3500; average 1070	< 1220; average 460	< 1220; average 460	< 1220; average 460	< 1055; average 750
Reservoir temperature (°C)	Not critical	< 121	< 121	Not critical	< 93; average 52	< 93; average 60	> 38; average 57	Not critical	Not critical	Not critical	< 75
Dipping reservoir > 15 °	Favorable to maximize gravity drainage	Favorable to maximize gravity drainage	Favorable to maximize gravity drainage	Favorable to maximize gravity drainage	Favorable to maximize gravity drainage	Favorable to maximize gravity drainage	Not critical	Not critical	Not critical	Not critical	Not critical
Reservoir heterogeneity	Fractures are unfavorable	Fractures are unfavorable	Fractures are unfavorable	Fractures are drastically unfavorable	Fractures are drastically unfavorable	Fractures are drastically unfavorable	Fractures are drastically unfavorable	Fractures are unfavorable	Fractures are drastically unfavorable	Clays are drastically unfavorable	Fractures are unfavorable
Water salinity (g/l NaCl)	Not critical	Not critical	Not critical	Not critical	< 100	< 100	Not critical	Not critical	Not critical	Not critical	< 100

Screening of Croatian fields

- every oil reservoir with > $1*10^6$ m^3 OOIP was subjected to the screening process (total of 41 reservoirs)
- automatic comparison of reservoir & fluid properties to screening criteria using any programming language
- 4 outcomes:
  - fully compatible – green
  - conditionally compatible – yellow
  - not compatible – red
  - not relevant – white

Screening of Croatian fields

Stock tank oil density	831	kg/m³
Oil viscosity	0,904	mPa*s
Oil saturation	38,1	%
Oil composition	High % C5 - C12	
Special components	No	

Formation type	Sandstone	
Reservoir depth	820	m
Reservoir temperature	60,2	°C
Permeability	50	mD
Porosity	28,6	%

Net pay	16,2	m
Dipping reservoir > 15 °	Yes	
Reservoir heterogeneity	No	
Water salinity	8,13	g/l NaCl

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Screening of Croatian fields

- total EOR potential in Croatia - 142 * 10^6 m^3 OOIP
- applicable EOR methods:
    1. CO_2 miscible flooding (24 optimal candidates)
    2. chemical flooding
    3. microbial EOR
    4. thermal methods
- some EOR methods are not applicable in Croatia

Conclusion

Step 1: EOR screening	**xxxxxxxxxxxxxxxxxxxxxxxx candidates**
Step 2: Rough prediction of future EOR production + coarse economic evaluation	**xxxxxxxxxxxxxx candidates**
Step 3: Laboratory and simulation studies + final economic verdict	**xxxxxxx candidates**
Step 4: Pilot project + calibration of numerical models	**xxxx candidates**
Step 5: Full field EOR project	**xxx candidates**