Effect Of CO2 Miscible Injection On Maximizing Oil Recovery And Storage Capacity In A low Permeability Fractured Reservoir

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conclusion

Site selection and characterization is one of the most important steps to perform CCS projects. In addition, a CCS project must be attractive enough and economical for investors and producers to prove it self. CO2 EOR projects could be one of priorities for CCS according to excess recovered oil when emission trade price is not high enough ,there isn't any financial assist like CDM and there is not serious emission penalty.

In the other hand ,CO2 EOR is not the sole solution for petroleum recovery and it must be proved for reservoir owners and production company due to reservoir and crude condition. This study shows that in low permeability low pressure fractured reservoirs oil reservoirs, when CO2 could be miscible with the crude , CO2 EOR has some advantages in comparison with Methane and Nitrogen which have higher minimum miscibility pressure and face with channelling and break trough easier.

In low permeability reservoirs, gas injectivity is limited and specially in fractured reservoirs , early break trough might be met easily. Injectivity could be increased for CO2 injection because of its ability for miscibility in lower pressure, injectivity is affected by miscibility ,consequently it can provide practical storage capacity .

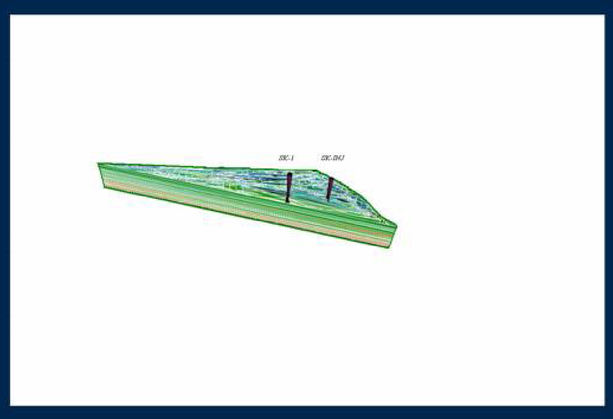
Thus such a reservoirs with light oil could be considered as potential candidate for CCS pilot or demonstration projects.

Field Description :

NM1 field is located in Zagros basin west part of Iran and was explored in 1969. The oil in place is estimated about 849 MMbbl with 5% recovery factor , 41 MMbbl could be produced. Production area is about 24400 Acer and production depth is 5729 feet under ground level . Reservoir contains carbonated fractured rock with average porosity 7 and water saturation 35% , gas cap drive and gas solution drive are assumed as main mechanism for oil production.

Current pressure is 2090 PSI but reservoir saturation pressure reported as 1850 PSI. The reservoir contains light oil with API 45.8 and started to production from 1990 with rate 1900 bbl per day which decreased to 1700 bbl per day in 2005.Up to end of 2005 , more than 9.5 MM bbl which is equivalent of 23 % of recoverable oil in place, has been produced in addition to 5.5 billion cubic feet gas.

According to predictions, production rate will fall below 1200 bbl per day before 2028 and new drilling can not be helpful because of reservoir low permeability.



In this study , several production scenarios have been studied and compared with natural depletion case. Methane , Nitrogen and CO2 injection considered for EOR . According to reservoir pressure , nitrogen and methane can not raise to miscible pressure and for these cases, injection planned into cap rock and immiscible scenario is followed.

In the other hand oil gravity allows miscibility in reservoir pressure for CO2 thus injection in the oil zone planned and simulated for CO2.

Simulation was started from 1990, start of production and continued to 2030 with limitation for GOR, water cut and minimum oil production rate. Maximum gas oil ratio(GOR) was set as 1500 scf per barrel oil , maximum water cut defined 5% and minimum economical rate of production was set as 500 bbl per day, software programmed in the manner if any of limitation break , well will be shut although in other runs , GOR limitation was removed to observe gas production.

Two injection rates ,5 millions standard cubic feet day and 10 millions were practiced for nitrogen injection. Simulation results shows that 5 millions scfd Nitrogen injection rate ,doesn't have any considerable effect on oil production , a small increase in production rate could be observed for less than 200 days and after that, negative slope in production could be seen. 1600 days after injection (less than 4.5 years) , reservoir will meet early break trough which at this point ,GOR reaches to 3000 rapidly and exceeds more.

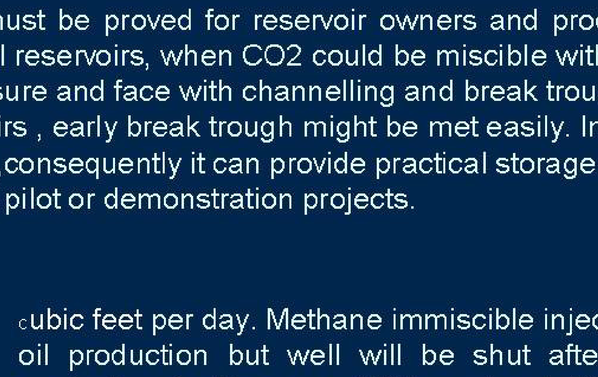
In 10 millions per day rate for Nitrogen, how ever production rate isn't increased , reservoir face with early break trough sooner. In this case، break trough is observed after 1200 days after injection which GOR exceed from 3000 rapidly and can exceed more than 5000 if well wont be shut.fig 1 shows the oil production rate which is expected by green line, cumulative oil production which shoed by red and GOR addressed by blue during Nitrogen injection.

Fig1 a,b-effect of 10 MMscfd Nitrogen and Methane immiscible injection on oil production rate

cubic feet per day. Methane immiscible injection also doesn't have considerable effect on oil production but well will be shut after 1500 days because of increase in gas production. In this case , GOR reaches to 2000 and exceeds rapidly.

Finally, gas flooding practiced for miscible CO2 with rates:5,10 and 20 scfd .production rate increase gradually in 5 millions scfd injection rate and rises to 2200 bbl per day with 5 millions scfd injection rate. Reservoir can continue to production 5200 days (more than 14 years) after injection then GOR exceeds than 1500 and well will be shut.

Simulation was also performed for methane with injection rate 10 millions standard With rate of 10 millions cubic feet of injection, how ever production rate rises to 2600 bbl per day but gas GOR exceeds than limitation 2400 days after injection and production couldn't be continued according to defined limitation. In comparison with two CO2 injection rate, 20 millions scfd case, shows better oil production rate however it face with break trough sooner .For rate of 20 millions scfd , break trough will accrue 2000 days after injection when production rate reaches to 2800 bbl per day. Effect of CO2 injection rate is shown in fig2 a-c.



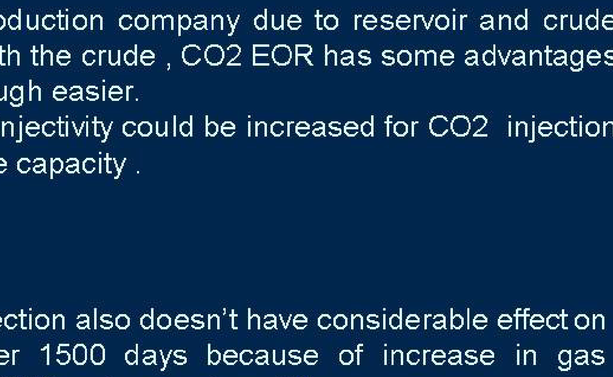


Fig2-a,b-effect of CO2 injection with rate 5, 10 MMscfd on oil production rate , cumulative production and GOR

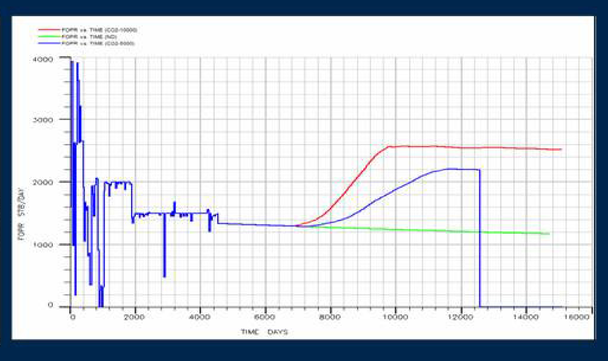


Fig2-c-effect of CO2 injection with rate 20MMscfd on oil production rate , cumulative production and GOR

Discussion and investigation:

It could be understood from simulation results that CO2 miscible injection has more better effect on reservoir production. Reservoir daily production can raise to 2800 bbl in rate of 20 MMscfd but it can not be continued for longer than 2000 days .according to cumulative production , 5MMscfd could be assumed as the best practice with 21 millions barrel production before shutting the well. This case can encourage production company to consider CO2 miscible flooding how ever a combined injection rate scenario could be considered in long time to obtain maximum cumulative production.

As GOR and break trough time view point, CO2 miscible with injection rate of 5MMscfd,CO2 miscible with rate 10 MMscfd injection rate and CO2 miscible injection with rate of 20 MMscfd , show best results respectively. For immiscible Nitrogen and methane , reservoir face with early break trough however it accurse for methane lather than rate of 10 MMscfd Nitrogen.

Total stored CO2 in the reservoir , is estimated in this study also in addition to gas composition at the end of injection time. results are shown in following table. It is understood from results that for injection rate of 20 MMscfd ,maximum storage capacity could be obtained, in this rate 1.921 millions ton CO2 could be stored before break trough. In 10 MMscfd scenario, 1.51 millions ton CO2 could be stored during 6.7 years of injection. Although in 5MMscfd injection rate scenario , flooding is continued for almost 14 years but storage just reach to 1.092 millions ton.

Injection rate MMscfd	Stored CO2 MMton	CO2 in produced gas at the end of injection %	CO2 in produced oil at the end of injection
5	1.092	60%	5%
10	1.51	62%	7%
20	1.921	64%	8%