THE CO_2 FLOODING: PROSPECT AND CHALLENGES ON MALAYSIAN OIL FIELD

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Abstract

This paper describes the potential of carbon dioxide flooding for enhanced oil recovery (EOR) for Malaysian oil fields. This paper also presents various problems that need further evaluation before embarking on the CO_2 project. The potential oil recovery from CO_2 flooding is estimated to be more than 500 million STB. The sources of CO_2 gas supply are nearby and plenty from the Malaysian gas field and Natuna gas field. Previous study had shown that Malaysian oil fields are suitable for immicible and miscible CO_2 flooding. This paper has identified some of the problems that need more studies to optimize the oil recovery and to provide relevant facilities for injection and processing purposes. Another problem that needs due attention is the economics of this project. As a start, a preliminary study on MMP of CO_2 - Malaysian crude was conducted at UTM [Hui, H.L, 1995]. Subsequently, in 1996, a study was initiated to investigate the application of foam for mobility control under CO_2 flooding [Sugiatmo et al, 1997].

Introduction

The Malaysian oil fields are separated in two regions, West and East Malaysia. The oil fields from West are Dulang, Guntong, Seligi, Semangkok, Tabu, and Tapis and from East Malaysia are Baram, Baronia, Betty, Bokor, Erb West, Saint Joseph, Samarang, South Furious, Tukau, and West Lutong. Malaysian oil fields are entering a more mature phase of development and it is now timely to consider enhanced oil recovery (EOR) development plans and potential [Egbogah et al.,1994 ; Hovdestad and Egbogah, 1995].

The ultimate recovery at 1994 in Malaysia is 6.95 billion barrels of oil, with remaining reserves of 4.3 billion barrels and oil production is about 630,000 barrels of oil per day, represents a reserves to production ratio of about 18 years. The fundamental reason is that CO_2 can efficiently displace fluid high pressure. It is miscible with crude oil. It is approximated that the average recovery factor is 30% of original oil in place and over 15 billion barrels of oil will remain unrecovered in Malaysian offshore reservoirs at the end of existing primary and secondary operations. Because of a lot of

CO_2 supply and reserve around this region CO_2 flooding is considered as a very potential EOR process.

Fundamental of The CO_2 Flooding Process

Since 1950, the use of carbon dioxide for improve oil recoveries in petroleum reservoirs have been investigated. Carbon dioxide in the liquid state (critical temperature is 87.8^{0}F, and critical pressure is 1073 psi) is a rather unique for oil recovery agent. Both laboratory and field studies have established that CO_2 can be an efficient oil displacing agent. The principle mechanisms believed to contribute to improve oil recovery in the CO_2 injection process are oil viscosity reduction, oil swelling, interfacial tension reduction, emulsification, blowdown, and well stimulation effects [Holm, L.M., and Josendal, V.A., 1974].

The method of CO_2 injection into a reservoir will result in either a miscible or an immiscible displacement. Miscible displacement occurs whenever the displacing gas is miscible in all proportions with the reservoir fluid under the prevailing reservoir pressure and temperature. On the other hand, immiscible displacement are those in which the equilibrium phases at the gas oil front essentially immiscible, and those in which the injected gas is sufficiently enriched at the front as to be completely miscible with the reservoir fluid. Miscible CO_2 flooding is best suited to light and medium gravity crude oils and the immiscible process may apply to heavy oils.

The Potential of CO_2 Flooding

The potential of CO_2 flooding for Malaysian oil fields is considered base on the additional recovery that can be achieved, the recovery mechanism and the supply of CO_2 gas. The study by Egbogah et al.,1994, Table 1 showed the summary of the EOR potential for East and West Malaysia oil fields. The oil fields in East Malaysia contain nearly 6 billion barrels STOIP and 11.5 TSCF gas initially in place and EOR potential in the major fields is estimated at 850 MMSTB. From West Malaysia approximately 5 billion STOIP and EOR potential could reach 740 MMSTB. Out of this 1.59 MMM STB the potential recovery by CO_2 flooding is additional to be more 500 million STB.

Initial study by Hui,1995, indicated that the estimated minimum miscibility pressure (MMP) CO_2 for Malaysian crude is in the range of 2300 to 4380 psig, which is higher than the reservoir pressures. It is possible to reduce the MMP of Malaysian crude-CO_2 mixture by blending the CO_2 with solvent such as ethane, propane and butane. As a guide, Table 2 shows the screening criterion for selection of suitable CO_2 flooding.

In addition to potential EOR reserve, the Malaysian oil fields are surrounded by large CO_2 gas reserve. The reserve of CO_2 from K5 field has approximately 7.2 TSCF and the surrounding area from Natuna gas field (Indonesia) is 157.62 TSCF. It shows great potential for the supply of CO_2 gas in this region [Egbogah et al. 1994 ; Sumarno et al. 1992].

Challenges in CO_2 Flooding Process

One of the major problems with the CO_2 flooding is the poor sweep efficiency. These phenomena are usually observed in the heterogeneous reservoirs. In certain reservoirs, the CO_2 is much lighter and less miscible than crude oil. In this case gravity overriding and viscous fingering may occur, which leads to poor sweep efficiency. Several methods have been studied. By combining water injection with gas injection as alternative slugs (WAG process), the volumetric sweep efficiency can be significantly improved by reducing the gas mobility in reservoir, which becomes close to the mobility of the water. Determination of slug size of water and gas is very important in this process. These methods still have many problems (water blocking) on field operations. Recently, these methods have been improved by using foam. Surfactant or polymer can be used as foaming agent. Foaming solution combined with injected CO_2 can generate foams that significantly reduced the mobility of the CO_2 (Stalkup, Jr., 1983). Work at UTM is concentrated on the CO_2-foam injection to control the mobility of CO_2 and MMP study.

The implementation of CO_2 flooding needs large quantity of CO_2 gas. The amount of the CO_2/oil ratio vary from around 26 MSCF per barrel oil produced. It is a challenge to provide and transport this large amount of CO_2 . Separation and transportation/transmission of CO_2 is second major challenge in CO_2 flooding project from its source to point of injection with the required quality. Large scale CO_2 separation and purification using membrane technology can provide the required purity. More studies on large capacity and better performance membrane are necessary. Transportation of CO_2 from the source to the desired location is quite a distance, which is more than 400 km. It is possible to have pipe line from K5 (Serawak) to Natuna Gas Field and then to the Malaysian Peninsular oil fields. The pipe lines and other injection and production facilities should be able to withstand the corrosive nature of the CO_2 and high pressure. This problem creates R&D opportunities for the development of cheaper and better material.

The economics of a CO_2 EOR project does not only depend on cheaper and better facilities but it also depends on the overall cash flow structure of this projects.
From Dabbous review (1996), approximate cost breakdown for CO_2 flood project in dollar per barrel of oil produced is shown in Table 3. Total cost is in the range 16 to 27 US$/BOE. However, Fox (1996), has shown that by implementing new technologies significant cost reduction can be achieved. The total estimated cost from 18.20 $/BOE was reduced to 10.25 $/BOE on CO_2 flooding operation for Permian Basin, USA (see Table 4). The Malaysian oil fields are located offshore which of course increase the overall cost for implementing CO2 project on these fields. One away to make this project attractive is by giving special and better incentives for operators who implement the EOR projects.

Conclusion

1. Additional oil recovery by CO_2 flooding processes is more than 500 million STB of oil.
2. Supply and reserve of CO_2 from Malaysian and Natuna gas fields are capable of supporting this project.
3. The suitable CO_2 flooding processes for Malaysian oil field are immiscible and miscible displacement process. Previous study at UTM had shown that MMP of CO_2 crude oil could not be achieved in Malaysian reservoir. Study of CO_2 solvents blend is needed to further reduced the MMP.
4. Studies should be conducted to reduce mobility of CO_2 and to improve displacement efficiency of CO_2 flooding, especially in heterogeneous reservoirs. Presently UTM is conducting CO_2 foam study to control the CO_2 mobility.
5. Economics and technical studies must be carried out on the process and transport of the CO_2 from its source to the point injections. Joint venture projects between Malaysia, Indonesia, Thailand and Vietnam can be implemented to provide integrated transmission network and CO_2 processing in this region.
6. Thorough economics feasibility study on the over all CO_2 enhanced oil recovery project in Malaysia must be investigated. The study should include oil and CO_2 gas pricing, incentives in the PSC to encourage EOR implementation and CO_2 tax for environmental issues.

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TABLE 1- SUMMARY OF THE EOR RESERVES ADDITIONS IN MALAYSIA OIL FIELDS (From Egbogah, 1994)

	STOIIP MMSTB	EOR Potential MMSTB
West Malaysia	5000	740
East Malaysia	5660	850
Total	10660	1590

TABLE 2- TECHNICAL SCREENING GUIDE FOR CO_2 INJECTION PROCESS (From Egbogah et al, 1994)

Screening Parameter	Field Proven Technology	Current Technology	Future Technology	Dulang Field
A. <u>Crude Oil</u> 1. Gravity (^{0}API) a) miscible CO_2 process b) immiscible CO_2 process	 ≥ 24 ≥27	 ≥ 24 ≥27	 ≥ 20 ≥25	38-39.91
2.Oil Viscosity, Cp a) miscible CO_2 process b) immiscible CO_2 process	 ≤2 ≤10	 ≤5 ≤50	 ≤10 ≤100	0.88-6.0
3. Crude oil composition	MMC	MMC	MMC	MMC
B. <u>Reservoir</u> 4. Depth (m) a. miscible CO_2 process b. immiscible CO_2 process	 <1000	 <800	 NC <800	1146-1451
5. net thickness m)	NC	NC	NC	NC
6. Temperature (^{0}C)	NC	NC	NC	50
7. Porosity (fraction)	NC	NC	NC	30
8. Permeability (mD)	≥100	≥50	≥10	266-324
8. Pressure, psia	≥MMP	≥MMP	≥0.8 MMP	1800
9. Oil Saturation at start process(%) : a. miscible CO_2 process b. immiscible CO_2 process	 >20 >50	 >20 >40	 >20 >20	 >20 >20
Key : NC : Not a critical factor MMC : Minimum miscibility composition MMP : minimum miscibility pressure				

TABLE 3- COST CO_2 FLOOD PROJECTS IN DOLLAR US
(From Dobbous, 1996).

Cost	US$/bbl
Investment cost	1-4
Operating cost	3-7
CO_2 cost	12-16
Total	16-27

TABLE 4- PERMIAN BASIN CO_2 FLOOD COSTS HAVE FALLEN
(From Fox et al 1996)

Cost Component	1985 Projects US$/BOE	1995 Projects US$/BOE
Capital	1.50	0.80
Operating expense	5.00	2.60
CO_2 Purchase	6.50	3.25
Royalty, PPT &Insurance	5.20	3.60
Total	18.20	10.25