PENGGUNAAN BUSA UNTUK MENGAWAL MOBILITI

DALAM BANJIRAN CO_2-BUSA

SUGIATMO

Tesis ini dikemukakan
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ABSTRACT

The objective of this thesis is to study the mechanism of foam flow that occurs in porous media during CO_2-foam flooding process. One of the influential factors affecting the mechanism of foam flow in porous media is the flow rate. The experimental work was performed at flow rate ranging from 0.0001 to 2.5000 ml/min. This thesis determined the effect of the flow rates on foam flow mechanism in porous media. Micromodel was used as the porous media in order to enable the observation of the foam movement. The phenomena of the foam flow mechanism were recorded using video tape. The type of surfactant used in this experiment was alpha olefin sulphonate (AOS) at concentration of 1.00 wt.%. The oil phase was various synthetic oil (e.g. hexane). The experiments were conducted at room conditions. The results of the study showed that the mechanism of foam flow in porous media are reforming and breaking process of foam in porous medium. At condition of high flow rates (>1.0000 ml/min) the mechanism of foam flow is dominated by the snap-off. while at the condition of low flow rates (<1.0000 ml/min). it is dominated by the coalescence capillary suction and gas diffusion. The interaction between oil and foam in porous media was categorized as non-oil spreading phase (such as micro emulsion) on the foam surfaces. The mechanism of oil flow was observed as network of oil on foam surfaces. Due to the coalescence capillary suction and snap-off processes. the trapped oil in porous media was displaced to the outlet. In the presence of foam in porous media with coalescence capillary suction and snap- off mechanisms have succeeded in controlling mobility of CO_2-foam flooding.

KANDUNGAN

BAB 1

PENDAHULUAN

1.1 Latar Belakang Masalah

Kaedah perolehan minyak tertingkat (EOR, enhanced oil recovery) bertujuan untuk meningkatkan prestasi perolehan minyak pada suatu lapangan minyak. Terdapat empat jenis kaedah perolehan tertingkat iaitu kaedah kimia, banjiran terma, banjiran gas dan suntikan mikrobial (Lake, 1989; Moritis, 1990). Salah satu kaedah banjiran gas yang lazim digunakan ialah banjiran CO_2 (Moritis, 1990; Hadlow, 1992).

Terdapat enam mekanisma yang bekerja dalam banjiran CO_2 (Mungan, 1991), iaitu: (1). penurunan tegangan antara permukaan (IFT) menjadi sifar (larut campur) atau mendekati sifar (near miscible), (2). penurunan kelikatan minyak, (3). pengembangan minyak (oil swelling), (4). pengemulsian minyak, (5). penghembusan (blow down) dan (6). kesan rangsangan telaga (well stimulation). Huraian yang lebih rinci mengenai banjiran CO_2 tersebut akan dijelaskan dalam BAB II.

Dalam proses penyesaran minyak oleh CO_2 terdapat beberapa faktor yang menentukan iaitu sifat batuan dan bendalir reservoir, kecondongan reservoir, tekanan reservoir, kehetrogenan reservoir, ketertelapan relatif dan ketepuan minyak di dalam formasi (Mungan, 1984, 1991). Untuk mendapatkan proses banjiran CO_2 larut campur yang berkesan perlu ditentukan tekanan larut campur minimum yang nilainya amat dipengaruhi oleh graviti minyak, komposisi minyak dan suhu reservoir (Holm dan Josendal, 1982; Stalkup, 1983). Selain itu darjah keheterogenan reservoir (misalnya, ketertelapan batuan dan keheterogenan batuan) yang tinggi akan mengurangi keberkesanan proses penyesaran tersebut (Jarrel *et al.* 2002).

Pada pelaksanaan di lapangan, proses banjiran CO_2 mempunyai kecekapan sapuan yang rendah iaitu sekitar 60% (Stalkup, 1983; Klins, 1984). Terdapat dua punca utama yang dapat menyebabkan ia mempunyai kecekapan sapuan yang rendah. Pertama, disebabkan oleh perbezaan antara mobiliti CO_2 dan mobiliti minyak yang begitu besar. CO_2 mempunyai kelikatan yang lebih rendah daripada kelikatan minyak, yang menjadikan nilai mobiliti CO_2 sangat tinggi dibandingkan dengan mobiliti minyak. Keadaan ini mengakibatkan terjadinya penjejarian likat (viscous fingering) yang dapat menyebabkan terjadinya masa bolos awal (early breakthrough). Fenomena penjejarian likat lebih ketara di dalam batuan reservoir yang heterogen (Stalkup, 1983; Christie, 1991). Kedua, CO_2 lebih cenderung untuk bergerak di bahagian atas reservoir. Hal ini disebabkan oleh nilai ketumpatan CO_2 yang lebih kecil daripada ketumpatan minyak. Akibatnya sebahagian besar CO_2 yang disuntikan akan mengalir ke bahagian atas reservoir. Kesan ini lebih dikenali sebagai kesan pemisahan graviti (Smaoui dan Gharbi, 2000).

Beberapa usaha telah dilakukan untuk meningkatkan kecekapan sapuan banjiran CO_2. Terdapat dua kaedah yang popular iaitu kaedah suntikan air berselang seli dengan gas (Water Alternated Gas, WAG) dan suntikan surfaktan berselang seli dengan gas (Surfactant Alternating Gas, SAG) . Dalam kaedah WAG, air disuntik berselang seli dengan CO_2 untuk tujuan mengawal mobiliti CO_2 (Hadlow, 1992; Martin dan Taber, 1992). Akan tetapi, Christensen, Stenbey dan Skauge (2001) yang melakukan evaluasi projek pada lapangan yang telah dilakukan kaedah WAG mendapati bahawa kaedah WAG banyak menimbulkan masalah. Di antara masalah utama yang dihadapi adalah penghadangan oleh air (water blocking), sehingga ketepuan air terus meningkat di seluruh bahagian reservoir. Akibatnya CO_2 didapati kurang berkesan dalam menyesarkan minyak.

Selanjutnya di dalam kaedah SAG, larutan surfaktan disuntik berselang seli dengan CO_2 dengan tujuan untuk menghasilkan busa di dalam reservoir (Bernard *et al.* 1980; Martin *et al.* 1992). Di antara masalah yang dihadapi oleh SAG adalah jumlah kuantiti busa yang diperlukan dengan kualiti busa tertentu tidak mencukupi (terbentuk) di dalam reservoir ("foam bank"), sehingga busa didapati kurang berkesan di dalam menyesarkan minyak. Di samping itu busa tidak stabil pada keadaan reservoir (Dietz, 1985).

Beberapa kajian terdahulu telah mempelajari penggunaan busa untuk mengawal mobiliti CO_2 (Heller dan Taber, 1980; Grigg dan Schechter, 1996). Di antara faktor-faktor yang dapat mempengaruhi mobiliti busa tersebut adalah kualiti busa, kepekatan surfaktan, halaju alir gas, minyak dan ketertelapan batuan (Yaghoobi dan Heller, 1994; Chang dan Grigg, 1998; Mannhardt dan Svorstol, 2001). Di samping itu, kajian-kajian yang telah dilakukan pada projek rintis (Aarra *et al.* 1996; Chalbaud *et al.* 2002) dan pemantauan di lapangan (Hofner dan Evans, 1995; Blaker *et al.* 2002) menunjukkan bahawa proses banjiran CO_2-busa memberikan kesan positif dan memberi pulangan ekonomi. Akan tetapi, kebanyakan kajian-kajian tersebut dilakukan secara makroskopik ataupun megaskopik. Disamping itu, keputusan kajian tersebut tidak mampu untuk menjelaskan secara terperinci mengenai bagaimana busa dapat mengawal CO_2 dan mekanisma aliran busa yang sebenar terjadi di dalam media berliang.

Untuk dapat menjelaskan bagaimana mekanisma aliran busa itu terjadi di dalam media berliang, maka dilakukan kajian pada skala mikroskopik. Antara penyelidik yang telah menjalankan kajian tersebut adalah Huh *et al.* (1988), Owette dan Brigham (1988) dan Rossen (2000). Dalam kajian tersebut mereka menggunakan mikromodel yang dibuat daripada kaca yang lut sinar. Kajian tersebut ditujukan untuk mendapatkan pemerhatian visual terhadap proses yang berlaku.

Salah satu faktor yang dapat mempengaruhi mekanisma aliran busa adalah halaju alir gas. Kajian terdahulu telah dilaporkan oleh Huh *et al.* (1988) dan Chamber dan Radke (1991). Huh *et al.* (1988) dalam kajiannya menggunakan halaju alir gas tinggi yang berjulat antara 10 sehingga 120 kaki/hari mendapati bahawa mekanisma aliran busa yang terjadi adalah dengan cara *pemutusan busa*, *pembahagian busa* dan *cantuman sedutan rerambut*. Hal yang berbeza dijumpai oleh Chamber dan Radke (1991). Chamber dan Radke (1991) dalam kajiannya menggunakan halaju alir gas sebesar 43 kaki/hari mendapati bahawa mekanisma *pemusnahan busa* dengan *cantuman sedutan rerambut* dan *resapan gas* adalah sangat dominan. Di samping itu juga Chamber dan Radke (1991) mendapati adanya mekanisma *pemutusan busa* seperti yang dijumpai oleh Huh *et al.* (1988). Dari keputusan Huh *et al.* (1988) dan Chamber dan Radke (1991) yang menggunakan halaju alir gas di atas 1.0 kaki/hari, tetapi menghasilkan keputusan yang berbeza atau kurang pasti mengenai mekanisma aliran busa yang dominan. Hal ini dapat disebabkan oleh model media berliang yang berbeza digunakan oleh para penyelidik tadi.

Di samping persoalan tersebut di atas, kesan adanya minyak terhadap busa juga perlu kajian lanjut. Hal ini disebabkan adanya percanggahan keputusan sama ada minyak akan memusnahkan busa atau menjadikan busa lebih stabil. Beberapa kajian terdahulu telah mendapati bahawa minyak mempunyai kesan positif dan negatif terhadap busa (Nikolov *et al.*, 1986; Kuhlman (1990, 1994); Schramm *et al.*,1994). Sebagai contoh kajian Nikolov *et al.* (1986) mendapati bahawa busa akan musnah bila bersentuh dengan minyak. Hal yang sama dijumpai juga oleh Kuhlman (1990, 1994). Selanjutnya, hal yang berbeza ditemukan oleh Schramm *et al.* (1994) yang mendapati bahawa busa lebih stabil apabila bersentuh dengan minyak. Perbezaan keputusan tersebut mungkin disebabkan oleh jenis minyak dan ketepuan minyak yang digunakan berbeza. Untuk itu, kajian mengenai kesan tindak balas antara busa dan minyak masih diperlukan untuk mengenalpasti adanya percanggahan tersebut di antara para penyelidik.

1.2 Objektif dan Skop Kajian

Objektif penyelidikan ini adalah untuk mempelajari mekanisma aliran busa yang terjadi di dalam media berliang dan kesan halaju alir gas terhadap mekanisma aliran busa pada proses penyesaran CO_2-busa. Di samping itu kajian awal turut mempelajari kajian durabiliti busa terdiri sebagai berikut : pemilihan kadar aliran gas, pemilihan jenis surfaktan dan pelbagai kesan (jenis surfaktan, campuran surfaktan, kemasinan, komposisi elektrolit dan minyak).

Skop kajian ini meliputi kesan halaju alir gas terhadap mekanisma aliran busa di dalam proses banjiran CO_2-busa. Untuk itu, berbagai halaju alir gas yang digunakan iaitu antara 0.0003 ($Nc=31.5 \times 10^{-5}$) sehingga 9.125 kaki/hari ($Nc=7.8 \times 10^{-1}$). Dengan menggunakan mikromodel (media berliang) diharapkan pengamatan visual akan mendapati fenomena mekanisma aliran busa dan tindak balas antara busa dan bendalir yang terjadi di dalam media berliang. Di samping itu juga dapat digunakan untuk membantu menjelaskan kaitannya fenomena mekanisma aliran busa yang terjadi dengan mobiliti busa.

1.3 Hipotetis Kajian

Dalam kajian ini akan dibuktikan bahawa mekanisma aliran busa yang terjadi di dalam media berliang didominasi oleh *pemutusan* busa (sebagai mekanisma pembentukan busa) dan *cantuman sedutan rerambut* busa (mekanisma pemusnahan busa) yang bergantung kepada halaju alir gas yang disuntikan. Terjadinya proses *pemutusan* busa berguna untuk memudahkan laluan kepada minyak dan juga mengawal pergerakan gas dan air formasi di dalam media berliang. Selanjutnya mekanisma aliran busa dengan proses *cantuman sedutan rerambut* pula membantu meningkatkan kecekapan sapuan dalam menyesarkan minyak yang berada di hadapan. Di samping itu tindak balas antara minyak dan busa mempunyai kesan yang akan menyebabkan busa cenderung untuk tidak stabil (mudah musnah) di dalam media berliang. Selanjutnya dengan mengenal pasti mekanisma aliran busa dan tindak balas antara minyak dan busa yang terjadi di dalam media berliang tersebut, maka diharapkan aplikasi kaedah SAG di lapangan akan berjaya.

1.4 Organisasi Penulisan Tesis

Struktur organisasi penulisan tesis dapat dibahagi kepada 8 bab, dimana BAB I menjelaskan latar belakang kajian, objektif kajian, skop kajian dan hipotetis kajian. Selanjutnya pada BAB II membincangkan teori dasar mengenai banjiran CO_2, manakala BAB III menjelaskan teori surfaktan, pencirian busa dan kestabilan busa. Selanjutnya BAB IV membincangkan kajian mikroskopik terdahulu mengenai mikromodel, mobiliti busa dan mekanisma aliran busa yang terjadi di dalam media berliang, peranan keterbasahan batuan pada kestabilan busa dan tindak balas antara busa dan minyak. Manakala pada BAB V menjelaskan kaedah kajian yang digunakan. BAB VI menerangkan kajian awal mengenai durabiliti busa. BAB VII menerangkan kajian mikroskopik mekanisma aliran busa di dalam media berliang. BABVIII adalah kesimpulan kajian dan cadangan penyelidikan lanjut selepas penyelidikan ini.

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