ASPHALTENE INDUCED FORMATION DAMAGE MITIGATION: A REVIEW

Okafor Henry Elochukwu

Mohammad Joukarborazjany

ABSTRACT

Asphaltene related problems have been the most widely reported organic deposit problem in the oilfield. The mitigation process to remedy the problem has cost operating companies enormous amount of money and time due to shut downs. To effectively mitigate asphaltene related problems, it is worthwhile to understand asphaltene itself and its behavior. Asphaltene deposition in the reservoir causes formation damage which disrupts the natural productivity of the reservoir. The process of remediation is identified and classified into three categories: predictive, corrective and preventive measures.

Keywords: Asphaltene, remediation, asphaltene precipitation, asphaltene deposition, mitigation, onset of asphaltene flocculation.

INTRODUCTION

Asphaltene is described to be a solubility class which is insoluble in n-pentane or n-heptane but soluble in benzene, toluene and xylene. Asphaltene is the heaviest portion of crude oil, polar in nature containing heteroatoms (Nitrogen, Oxygen and Sulfur) and (Nickel and vanadium) [1]. To further describe the physical nature of asphaltene, it is non-crystalline, non-volatile with no defined melting point [2][3]. Asphaltene is considered to be arranged in a ring structure of condensed aromatic nuclei with heteroatoms scattered around it, further investigation shows that with increasing molecular weight, both the aromaticity and heteroatoms present increases [4]. Molecular weight of asphaltene varies, because different method of determination of the molecular weight gives different result but in the range of several hundred to several thousand grams per mole has been reported in literatures [5][6].

The behavior of asphaltene in the crude is not fully understood, as some researches believed that asphaltene is dissolved in the crude as a true solution and the process of precipitation of asphaltene is completely reversible [7]. Others believe that asphaltene is suspended in the crude oil in a colloidal state and stabilized by resins, these resins acts as peptizing agent thereby forming a protective sheath on the surface of the asphaltene and thus preventing the precipitation of asphaltene [8].

The presence of asphaltene in the crude oil is not a problem but rather its precipitation and subsequent deposition as widely reported in literature. For example, Boscan field in Venezuela with 17% wt asphaltene, has no asphaltene related problems observed but Hassi-Massaoud field in Algeria with only 0.15% wt asphaltene, recorded production problems related to asphaltene precipitation and deposition [4]. As a result, it was concluded that light to medium crudes containing small amounts of asphaltene may create more asphaltene precipitation problems during primary production [9]. Asphaltene related problems do occur in heavy crude oil if they are destabilized by mixing with another crude oil or introducing an incompatible fluid during any operation. Generally, asphaltene are precipitated from crude oil when changes relating to thermodynamic conditions of temperature, pressure and composition occur.

PROCESSES OF ASPHALTENE DEPOSITION

Asphaltene precipitation

During EOR technique implementation (miscible flooding), displacing fluid such as CO_2, LPG etc. are injected into the formation with the objective of mixing with the crude oil [7]. This action changes the composition of the crude thereby leading to the instability of the asphaltene and subsequent precipitation. At this stage, the precipitates are formed when asphaltene particle forms a distinctive solid phase as they emerge from the crude. Other known processes that cause the precipitation of asphaltene in the crude include: streaming potential caused by the fluid flow in the porous media of the formation [10], primary depletion, acidizing treatment during stimulation operation and commingled production of incompatible fluids [11].

Asphaltene flocculation

The small particles which precipitated clumps together or aggregate at this stage to form large size particle, [5] explained that asphaltene flocculation occurs because of the reduction in the reservoir pressure below the onset asphaltene pressure at which fine particles of asphaltene aggregate to form larger particles.

Asphaltene deposition

At this stage the solid particle asphaltene can no longer be supported by the liquid, it then settles out and become deposited on solid surface. Two major ways asphaltene deposition causes formation damage include: by surface deposition and pore throat plugging or pore bridging, pore throat plugging is widely pronounced mode of asphaltene deposition [3].

Deposition of asphaltene in the porous media causes the asphaltene to block or plug the pore throat of the porous media, thereby resulting to the reduction of effective hydrocarbon mobility. It causes formation damage by impairing the permeability hence plugging the pore spaces in the reservoir, altering the wettability and increasing the viscosity of the reservoir fluid by nucleating water-in-oil emulsion [13]. Deposition of asphaltene also leads to restriction of flow in tubing, flowlines, production and processing facilities.

Formation damage is defined as the reduction in the natural productivity or injectivity of a producing formation. Generally, it is industry norm to prevent formation damage rather than treating it, though asphaltene-induced formation damage once it occurs is irreversible but it can be prevented or remedied as the case may be. If proper planning is not done prior to development and production stage, asphaltene-induced formation damage can affect the economics of the project. This will be as a result of cost accruing due to remediation process to mitigate the adverse effect of the damage and also the time required to shut-in the affected wells [24]. The responsibility lies on the operator and contractor to beforehand investigate the possibility of asphaltene-induced production problems. In most cases during appraisal and development stages, asphaltene-induced problems are difficult to unravel by mere intuition. It is wise to anticipate the possibility of occurrence rather than wait for it to happen.

To remedy the problems caused by asphaltene deposition in the formation, results to high cost and loss of production time due to time allowed for the employed technique to effectively remove the damage. Three methods for controlling asphaltene deposition in the formation are proposed namely: predictive, corrective and preventive [14] [15][19].

Predictive method

This method involves understudying the thermodynamic conditions such as pressure, temperature and composition which their alterations lead to the onset of asphaltene precipitation. This method supports the understanding of the colloidal stability and the process of aggregation. Predictive methods identifies at what point does asphaltene starts to precipitate out of the crude oil, this information is pertinent as it gives the operator a prior knowledge of what to expect from the crude in the reservoir and behavior during production. Onset of asphaltene is defined as the smallest amount of flocculants (pentane or heptane) required for asphaltene flocculation in a mixture of crude oil and a flocculants. To predict the onset of asphaltene precipitation, the following laboratory methods are used for detection of onset asphaltene precipitation or asphaltene flocculation [16][17][18].

- Gravimetric method
- Acoustic resonance technique
- Light scattering technique
- Filtration technique

During natural depletion of the reservoir, the reservoir pressure is continuously reduced. Onset of asphaltene pressure is the pressure below which asphaltene starts to precipitate, knowing beforehand the onset asphaltene pressure from the above mentioned techniques, the production scheme can be planned in a manner to operate above the onset of asphaltene precipitation pressure for as long as possible.

Increase or decrease of reservoir temperature leads to asphaltene precipitation and flocculation. If enhanced oil recovery operation is to be employed later in the life of the reservoir to recover residual oil, for crude oil which is prone to asphaltene precipitation, enhanced oil recovery techniques such as steam injection and in-situ combustion which increases the temperature of the reservoir system should not be employed because it will certainly stir up the precipitation of asphaltene from the crude. Nitrogen gas injection is another EOR technique not to be considered because of nitrogen cryogenic nature which reduces the temperature of the reservoir system and also it has the capacity to alter the composition of the crude oil thereby causing the precipitation of asphaltene.

Paraffin deposit can occur with the combination of asphaltene, the common method of paraffin wax removal is by hot oiling which introduces an increase in temperature in the formation thereby triggering the precipitation of asphaltene. Thus, for dual occurrence of paraffin wax and asphaltene hot oiling removal technique is not to be used as a mitigation method. Stimulation procedure such as steam soaking is not to be considered, though unlike enhanced oil recovery steam soaking operation is not far away from the wellbore and at the wellbore precipitation and deposition of asphaltene which causes formation is said to be severe.

At the production stage, it is necessary for all fluid types to be injected into the reservoir to undergo a compatibility test with the reservoir fluid. Knowing beforehand the effect of a fluid additive is a sure way to prevent asphaltene related problems.

Corrective method

Corrective method involves the use of chemical solution such as aromatic solvent, mechanical removal of asphaltene after it has precipitated and deposited. Asphaltene when deposited in the reservoir is irreversible and occurs throughout the reservoir but the effect of its deposition is severe at and around the wellbore, thereby causing formation damage which reduces the natural productivity of the formation. In all organic deposit all over the world, asphaltene is the most occurring and complex to mitigate. Over the years, aromatic solvent such as benzene, toluene and most times xylene have been employed to remove asphaltene deposits.

The conventional method of asphaltene removal is by remediation process using aromatic solvents, these solvents possess the ability to dissolve asphaltene. In some severe cases of asphaltene deposition, frequent aromatic solvent wash is required to successfully remove the asphaltene. As a result, aromatic solvent of higher solvency potential is required to dissolve asphaltene. Commercially available solvents are available which are majorly laboratory blend of aromatic solvent and other chemical additives (dispersant) which are to perform the dual purpose of dissolving and preventing re-precipitation of asphaltene after dissolution. The wide application of aromatic solvent has its limitations due to health, safety and environment requirements. To avert this limitation, research has shown that alternative bio-solvents derived from natural sources such as soybean, palm oil, fermented carbohydrate etc. possess similar or greater solvency potential for asphaltene and other organic deposit and meet all health, safety and environment requirements.

Resins and asphaltene forms a micelle whereby resins acts as peptizing agent forming a protective layer around the asphaltene, thereby preventing precipitation of asphaltene. The presence of resins is important as it stabilizes asphaltene is the crude oil. For crude oil with low resin, there is high possibility of asphaltene precipitation. In this case, injection of dispersant will help to keep the asphaltene dispersed in the crude oil and prevent the aggregation of already precipitated asphaltene. Though, most times operators apply a mixture of specially formulated additives (inhibitors of asphaltene precipitation) and dispersant.

Alteration of production scheme is a corrective technique to ameliorate the deposition of precipitated asphaltene. Some of these techniques include:

- Reduction of excessive pressure drops in the formation.
- Reduction of shear.
- Reducing high production rate and maintaining a minimal economic production rate.
- Introduce only compatible fluids.
- Minimize mixing lower molecular weight alkanes.
- Reduction of velocity of fluid flow stream in the porous media has the effect of neutralizing asphaltene precipitated by electro kinetic effect.

Preventive method

Preventive method studies the conditions that will result in the precipitation of asphaltene in the reservoir and basically maintains the conditions of the reservoir at that state.

Researchers has reported using de-asphalted oil, de-asphalted oil (DAO) a mixture of all substances (saturates, aromatics, resins/maltenes) with the exception of asphaltene because it is being removed from the mixture. Addition of de-asphalted oil (DAO) into asphaltenic crude oil stream can be likened to as a way of increasing the resin/asphaltene ratio.

Asphaltene precipitation starts to occur as pressure in the reservoir approaches the onset of asphaltene precipitation pressure and maximum precipitation occurs at bubble point pressure, thus maintaining the pressure above the OAP will prevent precipitation of asphaltene. Civan and Wang proposed early pressure maintenance by water flooding is best to keep the reservoir pressure above the OAP [5].

Asphaltene deposition mitigation: Field cases

B.H Bay, Offshore China

Development on the B.C sand reservoir started in 1986. The crude oil produced from five wells contains high amount of asphaltene and other organic deposits with high viscosity. Between 1996 and 1997 diesel oil squeeze was used to clean formation wellbore, which increased the production level to certain level. This draws the conclusion that the formation was damaged as a result of asphaltene deposition in the near wellbore region. Full scale remediation process started in 1998, by injecting a specially formulated solvent whose principal components includes aromatics, polar corrective and dispersant. The remediation process was successful, as it was able to restore the formation permeability and increased production from 90 t/day to 270 t/day.

Marrat field, Kuwait

Marrat oilfield is located south east of Kuwait. It is a carbonate reservoir; it produces light medium crude with API gravity in the range 36^o to 40^o API. Reservoir pressure was around 9,500 psi, during primary production the pressure dropped to around 8,400 psi which is around the AOP (5,500 psi to 6,700 psi). If the reduction in reservoir pressure continues and reaches the AOP, this will trigger the precipitation, flocculation and deposition of asphaltene in the reservoir and also possibly result to formation damage. The decision was reached to close all wells and initiate a pressure maintenance program by water injection pending the outcome of a comprehensive investigation to predict and mitigate the effect of asphaltene precipitation and deposition.

To analyze the effect of asphaltene on the development of Marrat field, the following scenarios were investigated and simulated to optimize the process of development. This scenario includes: asphaltene behavior including precipitation, flocculation and deposition, formation damage and the effect on rock wettability and field performance including production of oil, gas and water.

Hassi Messaoud field, Algeria

Production from Hassi Messaoud field was from Cambrian sandstone at the depth of 11,000 ft, with pay zone in the range 100 to 300 ft thick. The original pressure was 6,825 psi and bubble point in the range 2130 psi to 2880 psi. The crude is described to be intermediate crude, light green color with API gravity of 42.3^o.

Asphaltene problems was first experienced in the tubing and the approach of cutting the asphaltene deposits via a wire line was too time consuming and later became unsuccessful. The operator resulted to chemical wash to remove the asphaltene deposits, to effectively remove the deposits, frequent chemical wash is required. It was discovered that by reducing the production rate which is achieved by opening the choke causes the asphaltene deposition to reduce.

This technique of reducing the production rate by opening the choke can be applied to asphaltene deposition in the formation. By opening the choke it helps to compensate for the loss in pressure due to formation damage as a result of asphaltene deposition.

Boscan field, Venezuela

Boscan field produces heavy crude oil with API gravity ranging from 9^o to 12^o. It contains large amount of asphaltene content about 17%. Boscan field puzzled most researchers with its uniqueness, because no asphaltene related problems was observed from this crude oil. Despite this, Boscan crude oil was used as remedial solvent to prevent asphaltene precipitation in other crude oil from other oilfield. Crude oil from Mata-Acema field was treated with acid, thus precipitating asphaltene from the crude oil, the same acid test was conducted on Boscan crude oil and no asphaltene precipitation was recorded. Boscan crude was mixed with crude oil from Mata-Acema and acid, the presence of Boscan crude prevented the precipitation of asphaltene from Mata-Acema crude. This implies that the Boscan crude acts as a protective sheath and prevent the contact of Mata-Acema crude with the acid.

ACKNOWLEDGMENT

My appreciation goes to those that supported us in the course of this work. We greatly appreciate your contributions. Thank you.

REFERENCES

[1] Samuelson., M.L (1992). Alternatives to aromatics for solvency of organic deposits. SPE Symposium of formation damage control. Louisiana.

[2] Hirschberg., A, Dejong., L.N, Schipper., J, and Meijers., J.G. (1984). Influence of temperature and pressure on asphaltene flocculation. Society of Petroleum Engineers Jounal, June.

[3] Siavash Ashoori, (2005). Mechanism of asphaltene deposition in porous media. Thesis for Doctor of Philosophy, school of Engineering, University of Surrey.

[4] Sunil., L.K., and Selim., G.S. (1995). Asphaltene: The cholesterol of petroleum. SPE paper 29787 presented at the SPE Middle East oil show held in Bahrain, 11-14 March.

[5] Civan., F. (2007). Reservoir formation damage. Fundamentals, modeling, assessment and mitigation. Gulf professional publishing, Burlington, USA, pp. 956-959.

[6] Speight., J.G, and Moschopedis., S.E, (1981). On the molecular nature of petroleum asphaltenes. American chemical society, advances in chemistry series, 195 pp. 1-15.

[7] Leontaritis., K.J, (1989). Asphaltene deposition: A comprehensive description of petroleum manifestation and modeling approaches. SPE production operations symposium, Oklahoma City, March 13-14.

[8] Sima Alian., Abdul., A.O., Ali., F.A and Irzie Hani (2011). Study of asphaltene precipitation induced formation damage during CO_2 injection for a Malaysian light crude. World academy of Science, Engineering and Technology.

[9] de Boer., R.B., Leerlooyer., K., Eigner., M.R.P, and van Bergen., A.R.D, (1995). Screening of crude oils for asphalt precipitation: theory, practice and the selection of inhibitors. SPEPF, February, p.55-61.

[10] Leontaritis., K.J, Amaefule., J.O, and Charles., R.E, (1994). A systematic approach for the prevention and treatment of formation damage caused by asphaltene deposition. SPE production and facilities, August, p.157.

[11] Kamran Akbarzadeh., Ahmed Hammani., Stephen Allenson., Jefferson Creek., Shah Kabir., Jamaluddin., A.J, Alan., G.M and Ryan P.R, (2007). Asphaltenes: problematic but rich in potential. Oil review.

[12] Salgaokar., L, and Danait., A, (2012). Environmentally acceptable emulsion system: An effective approach for removal of asphaltene deposits. SPE Saudi Arabia technical symposium and exhibition, 8-11 April.

[13] Leontaritis., K.J, (1998). Asphaltene near wellbore formation damage modeling. SPE formation damage control conference, Louisiana, 18-19 February.

[14] Mansoori., G.A, (2010). Remediation of asphaltene and other heavy organic deposits in oil wells and in pipelines. University of Illinois, January.

[15] Idem., R.O and Ibrahim., H.H, (2002). kinetics of CO_2-induced asphaltene precipitation from various Saskatchewan crude oil during CO_2 miscible flooding. Journal of Petroleum Science and Engineering, August, p.233-246.

[16] Wang., J.X, Buckley., J.S, (2001). An experimental approach for prediction of asphaltene flocculation. SPE paper 64994 presented at the 2001 SPE international symposium on oilfield chemistry, Houston, 13-16 February.

[17] Wang., J.X, Buckley., J.S, Burke., N.E, and Creek., J.L, (2004). A practical method for anticipating asphaltene problems. SPE production and facilities 19(3), August, p.152-160.

[18] Jamaluddin., A.K.M., Creek., J.L, Kabir., C.S, McFadden., J.D, D' Cruz., D, Manakalathil., J, Joshi., N, and Ross., B, (2002). Laboratory technique to measure thermodynamic asphaltene instability. Journal of Canadian Petroleum technology, 41(7), July, p.44-52.

[19] Thomas., D.C, Becker., H.L and Del Real Soria., R.A, (1995). Controlling asphaltene deposition in oil wells. SPE 25483 presented at the SPE production operation symposium held in Oklahoma City, March 21-23.

[20] Kelland., M.A (2009). Production chemicals for the oil and gas industry, CRC press.

[21] Hasket., C.E and Tartera., M, (1965). A practical solution to the problem of asphaltene deposits Hassi Messaoud field, Algeria. JPT 17, 387-391.

[22] Institute of petroleum 143/84 (1984). Asphaltene precipitation with n-heptane. London.

[23] Lichaa., P.M and Harrera., L, (1975). Electrical and other effects related to the formation to the formation and prevention of asphaltene deposition. SPE AIME paper 5304 presented at the international symposium on oilfield chemistry in Dallas, Texas, Jan 16-17.

[24] Newberry., M.E and Barker., K.M (1985). Formation damage prevention through the control of paraffin and asphaltene deposition. SPE paper 13796 presented at the SPE production operations symposium held in Oklahoma city, Oklahoma, 10-12 March.