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Suitability of Jatropha Oil as Surfactant in Steam Assisted Recovery of Nigeria Bitumen

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Abstract

More ways to improve the normal high rates of steam assisted bitumen recovery techniques such as SAGD (Steam assisted gravity drainage) and CSS (Cyclic steam simulation) have been studied for some years now, and It has been discovered that the addition of surfactants on ore or injecting it with steam has recovered more bitumen than the injection of the typical steam, but due to the cost and reduction in availability of petro surfactants feed stock and the food competition created by using an edible feedstock for biodiesel surfactant there is need for the use of an alternative feedstock for biodiesel surfactants. In this project, the focus is on the use of jatropha oil (a non-edible feedstock) for biodiesel surfactant production was proposed.

The paper features series of experiments that were carried out to compare the strength of extraction of bitumen from tar sands using steam from water and steam or vapor from biodiesel (jatropha biodiesel) water mixture after spraying the core with biodiesel and finally toluene**.** The core was modified from the tar sand gotten from Imeri village in the southwestern part of Nigeria. The samples treated with biodiesel had better and improved recovery than the one with just steam from water, while toluene gives the over-all best recovery.

Keywords*: Jatropha oil; Surfactant; Oil recovery; Nigeria bitumen.*

1. Introduction

SAGD and CSS have proven to be the most effective thermal techniques in bitumen extraction from deep oil sands as they efficiently address factors that tend to reduce recovery of bitumen reservoir by a relative increase in reservoir temperature. In these methods, steam injected into a subsurface oil sands seam, condenses due to thermal energy losses and forms bitumen-water emulsions, which may be recovered by means of production wells [1-3]. Asphaltene fractions in the bitumen promote the formation of bitumen-water emulsions under thermal recovery conditions, and they act as surfactants reducing surface and interfacial tensions, thereby helping to break down the oil sands ore structure and promoting the release of bitumen from the ore [4-7].

Babadagli *et al.* [3] conducted steam assisted bitumen recovery experiments to determine the high recovery potential and efficiency increase of Tall and canola oil biodiesel and they compared it with recovery from injecting steam only. The first set of steam assisted bitumen recovery tests were performed on sands ore (8.5% bitumen, 86.2% sand, 4.9% moisture) using atmospheric pressure steam and injecting a canola oil derived BD at 1 g/kg-bitumen dosage into the low pressure steam line. The cumulative bitumen-water emulsion products were collected every 30 minutes intervals, and their bitumen contents were determined using the Dean-Stark extraction. The result shows that biodiesel dosages increase bitumen recovery efficiency in the early phase of the test. The disadvantage of the study is that canola oil is edible and the cost of canola seed is average $630/ton as at June 2013 which is expensive compared to jatropha oil which is $140/ton. Researches on the applications of jatropha oil in the bitumen extraction and processes have been advanced in the recent time because of its market price, oil yield and not competition with human food. For instant Fadairo *et al.* [6] use the oil extract from jatropha for determining the softening point of Nigeria bitumen.

Use of surfactant additives to improve the efficiency of these thermal processes has been studied extensively over the decades [7] and the use of biodiesel or FAMEs as a surfactant addictive have shown to improve the efficiency of thermal processes [3]. Biodiesel or FAMEs which is produced from the transesterification of edible and non edible feedstock (fatty acid glycerides) have shown to wet bitumen and water because of their hydrophilic ($COOCH_3$) and hydrophobic (C_nH_m) functional groups, thereby promoting the production of bitumen when introduced to oil sands. The use of edible feedstock for production of biodiesel poses problems to humans in terms of food completion, so we proposed the use of a non edible feedstock (jatropha oil) to produce jatropha biodiesel for the extraction of bitumen from oil sands via steam assisted recovery. Jatropha oil is produced from *Jatropha curcas, L.* seed which grows in tropical and subtropical climates across the developing world; it is very cheap feedstock compared to other feed stock.

This study used jatropha biodiesel in steam assisted bitumen recovery from oil sands gotten from Imeri village in the Southwestern region of Nigeria and compared it with the ordinary steam recovery of bitumen,

2. Methodology

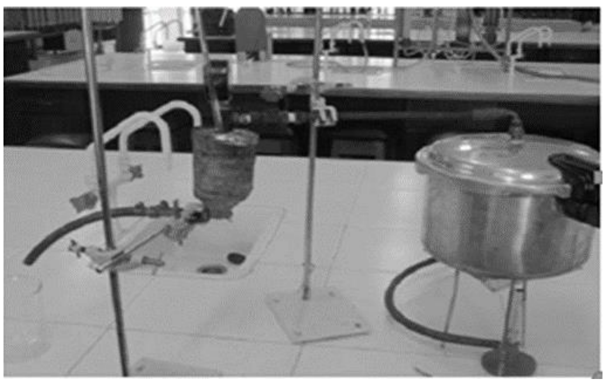

Figure 1. Pressure pot extractor set-up in Core Laboratory at Covenant University

The paper featured both the use of a pressure pot extractor to extract the bitumen from the core and Soxhlet extraction methods. The pot was modified to inject steam into an insulated chamber so has to extract heavy bitumen from the medium (core) inside the chamber (Figure 1), the extract along with condensed steam flows outside the chamber through an outlet connected to the end of the chamber. The extractor was designed and built to fulfill production situations where the pot and the connector act as the injector, the chamber with the medium in it serves as the reservoir, and the outlet is the producer.

2.1. Core preparation

The oil sands were gotten from Imeri village in Ondo state having a composition of 76% sand, 20% bitumen and 4% water. The oil sand was mixed with a larger proportion of sand in different percentages to form cores, the reason for mixing was because bitumen sand comes in molten form and would not readily form the core, so sand was added for the core to modify. The composition of the cores is given by the Table 1.

Table 1. Sample composition before experiment

Sample ID	Solvent	Solvent (mL)	Sample (g)	Bitumen (g)	Solid in Ore (g)
S1	Steam	300	223	89.2	133.8
S2	Steam	300	25.6	2.048	23.14
S3	Steam	300	26.8	1.876	24.55
S4	Steam	300	28.62	1.7172	26.56
S5	Steam	300	26.7	1.335	25.1
S6	Steam	300	27.7	1.108	26.37
BD1	Steam+Bio-diesel	300(25% BD)	226	90.4	135.6
BD2	Steam+Bio-diesel	300(25% BD)	23.3	1.864	21.06
BD3	Steam+Bio-diesel	300(25% BD)	27.4	1.918	25.1

Sample ID	Solvent	Solvent (mL)	Sample (g)	Bitumen (g)	Solid in Ore (g)
BD4	Steam+Bio-diesel	300(25% BD)	27.8	1.668	25.8
BD5	Steam+Bio-diesel	300(25% BD)	26.1	1.305	24.53
BD6	Steam+Bio-diesel	300(25% BD)	27.35	1.094	26.03
T1	Toluene	300	234.8	93.92	140.88

3. Experiments

The purpose of the work was to determine the effect of adding jatropha biodiesel in steam assisted bitumen recovery. The initial experiment, a pilot test involves using a Soxhlet extractor (Figure 2) for bitumen extraction from three (3) tar sand samples using different solvents (steam only, jatropha biodiesel assisted steam and toluene).

Figure 2. Setup of Soxlet extraction for the pilot tests at Covenant University Petroleum Laboratory

The samples were labelled S1, BD1, and T1, which were denoted as steam only, jatropha biodiesel assisted steam and toluene respectively. The results obtained for jatropha biodiesel assisted steam showed high and improved recovery than the results obtained using steam from water alone as shown in Table 2. This prompted and advanced the study to carry out ten (10) more extractions using the fabricated heating mantle (pressure pot), five of the extraction were carried out using by steam injection denoted as case 1 (samples S1, S2, S3, S4, S5), and the other five extractions where carried out by injectting biodiesel assisted water vapor or steam denoted as case 2 (Samples B1, B2, B3, B4, B5). The experiment using jatropha biodiesel assisted steam featured the spraying of jatropha biodiesel on the core as a surfactant and later the injection of steam or vapor from a mixture of 3000mL of water and biodiesel.

Table 2. Results obtained from three (3) tar sand samples using different solvents

Type of Solvent for Extraction	Vol. of solvent (mL)	Wt. of solvent (g)	Wet sample after extraction (g)	Bitumen extracts (g)	Unrecovered bitumen (g)	Bitumen recovered (%)	Bitumen unrecovered (g)
Steam	300	308.3	227.7	19.38	69.82	21.7	78.3
Toluene	300	249.6	221.9	38.1	55.82	40.6	59.4
Steam Assisted Jatropha Bio-diesel	300*	347.1	229.4	30.8	59.6	34.1	65.9

(25% BD)

The cores labeled S1-S5 were extracted by steam and the cores labeled B1-B5 were extracted by biodiesel assisted steam**.** The mode of extraction was done to study the strength of extraction of oil from tar sand by injecting steam from water and the strength of extraction of oil from tar sand by steam injection of water biodiesel mixture after spraying biodiesel on the core. The extraction is based on pressurized steam from water and biodiesel, the injected steam or vapor temperature is lesser than the boiling point of the fluids or solvent involve. During the extraction, steam is produced by heating the fluid to about or above boiling point in a particular medium, and the steam passes through a channel into a medium that holds or house the core, the steam forces oil out of the core leaving the residue.

Table 3 shows the results of the pilot test (S1, BD1, and T1) and the first five cores labeled S1 to S6 which were extracted via steam injection; it can be observed that as the Mass percentage fraction of bitumen decreases the extraction strength of steam reduces as percentage recovered becomes rapidly lower. The resulting condensates and extract from steam injection only were observed to stick to the gas beaker like bitumen to rock surface. The average temperature of extraction at 94°C and time of extraction was 4hrs.

Table 3. Effects of jatropha bio-diesel, water, and toluene on bitumen ore extraction

Sample ID	Extraction solvent	Wt. of recovered bitumen (g)	Wt. of unrecovered bitumen (g)	Bitumen recovery (%)	Percentage unrecovered (%)
S1	Steam	19.38	68.82	21.7	78.3
S2	Steam	1.5	0.548	73.6	26.4
S3	Steam	1.28	0.596	69	31
S4	Steam	1.16	0.5572	68	32
S5	Steam	0.8	0.535	60	40
S6	Steam	0.6	0.508	55	45
BD1	Steam+Bio-diesel	30.8	58.6	34.1	65.9
BD2	Steam+Bio-diesel	1.63	0.234	88	12
BD3	Steam+Bio-diesel	1.6	0.318	84	16
BD4	Steam+Bio-diesel	1.3	0.368	78	22
BD5	Steam+Bio-diesel	1.1	0.205	85	15
BD6	Steam+Bio-diesel	0.8	0.594	74	26
T1	Toluene	38.1	55.82	40.6	59.4

Samples labeled B1 to B6 that were sprayed by biodiesel first and were later extracted via injection of steam from water biodiesel mixture shows a higher percentage of bitumen recovered and as the percentage fraction of bitumen decreases extraction strength reduces but not rapidly. During the experiment it was witness that at a low temperature of 50°C the biodiesel in the mixture started vaporizing forming a foamy like substance which is channeled to the chamber and the resulting condensates and extract were observed all in a liquid suspension in the glass beaker i.e. the bitumen did not stick to beaker like in steam injection, it was soluble in the liquid suspension. The average temperature of extraction at 94°C and time of extraction was 3:30 hrs.

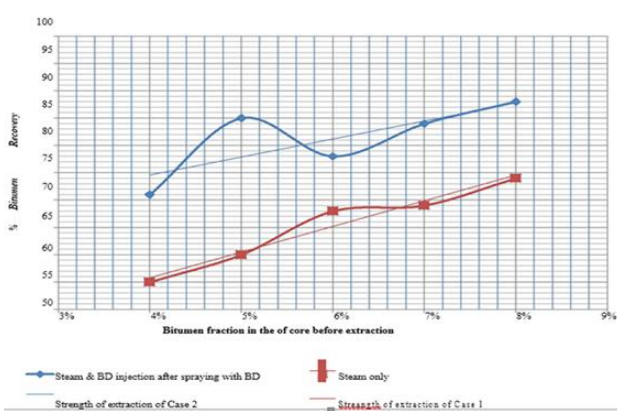

Figure 3 Percentage bitumen recovered vs. bitumen saturation of core samples

Analysis of figure 3: The graphs show the resultant recovery from the two methods; the biodiesel extraction curve is placed at a higher level than the steam extraction curve, therefore, showing that biodiesel had better recovery rates than ordinary steam. It also shows that the decline in the strength of extraction in steam is steeper than that of biodiesel i.e. steam injection will fail for more consolidated bituminous reservoirs where bitumen is drier than biodiesel. This can be attributed to the level at which the core was saturated with biodiesel when it was first sprayed on the core.

4. Discussion

The tables and graph above shows that Case 2 extraction method yielded more bitumen than Case 1 and this can be attributed to the effect of method and practices carried out in Case 2; which are

4.1. The effect of spraying biodiesel on the core

FAMEs (Fatty Acid Methyl Ester) have proved or been observed to wet both bitumen and water because of their hydrophobic (C_nH_m) and hydrophilic ($COOCH_3$) functional groups. Surfactant behavior of (JOFAME) Jatropha, oil Fatty Acid Methyl Esters, promotes wetting bitumen with water, so when jatropha biodiesel was sprayed into the core, it reduced the interfacial tension between bitumen and the sand particles at the surface making it easier for condensed vapor or steam to wet the core and mobilize bitumen for movement. But, since the core was already solidified sprayed biodiesel could not saturate the whole core as it could only penetrate cracks in the core, leaving a large volume (especially the inner part of the core) unsaturated.

4.2. The effect of injecting biodiesel -water vapor

The initial purpose of adding biodiesel to water was to generate steam or vapor with a fraction of biodiesel in it so as to ensure that the surfactant is continuously introduced in the core at any time during the extraction, so as to make up for the unsaturated volume of the core. But, during extraction when part of the biodiesel water mixture (80% biodiesel & 20% water) had to be injected first because its early vaporization, the effect was considered to be

- The early start time of thermal extraction as BD vaporizes earlier than steam
- Increase in saturation of surfactant in the core before actual steam from water is injected there by increases mobility of bitumen in the core
- Starts recovering bitumen before steam is generated in the water.
- Helps in the general mobilization of bitumen extract from the core into liquid suspension as seen in the extracts of Case 2

This was termed the **"first injecting phase"** in Case 2. After the BD water vapor goes, the larger fraction of water reaming is continuously heated till steam is generated

4.3. The effect of injecting steam from remaining water in Case 2

The initial purpose of Water was to create steam to assist in bitumen recovery and to also assist in creating a drive mechanism for Biodiesel to the core so as to create a continuous surfactant delivery to the core during extraction time. But, part of the biodiesel water mixture vaporized and had enough drive to reach the chamber, the effect of the remaining steam that was generated or injected when the temperature was about 88- 92°C or when water reached its boiling point where considered to be

- It increased the temperature of the chamber which favored viscosity reduction of the bitumen in the core.
- It continued the thermal extraction that started when part of the mixture vaporized earlier, and it cleans the residual bitumen left by the first vaporized mixture.

It has a longer injection and extraction time than the earlier vaporized BD and water. And was term as the **"second injecting phase"** in Case 2

4.4. The Effect of Varied Time on the Extraction Performance on both Case 1 and Case 2

The time taken for steam only to extract bitumen in a solidified core where sand particles are not produced is more than when bitumen are already lose from the sand particles by surfactant action in the same production condition. So the time of extraction For Case1 was longer so as to yield good recovery rates, but Case 2 took a lesser time of extraction not only because the bitumen is lose from sand particles but the solvent injection was in two phase (BD & water) and steam and had better recovery rates than Case 1.

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5. Conclusion

The use of thermal methods in bitumen recovery in places where oil sands have large deposits like the Alberta oil sand deposits in Canada has increased due to increase in heavier oil demands because of the failing conventional oil market and its rapid depletion. These thermal methods (Steam injection) have shown high recovery rates even in the experiment carried out in this study (Case 1), but laboratory results of Case 2 (use of jatropha biodiesel as an additive in a steam injection) have shown to have higher recovery rates than steam injection only.

The paper also justifies the use of a non-edible, cheaper feedstock for biodiesel production, which was used as surfactant addictive in steam assisted bitumen recovery from oil sands.

Acknowledgments

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