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SENSITIVITY ANALYSIS ON THE FACTORS AFFECTING CRUDE OIL EMULSION STABILITY

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Abstract

Production of water in oil emulsions is a common feature in crude oil production from mature fields and this can be completely controlled or avoided entirely. Typically, emulsion presence always gives rise to an increase in viscosity and this can ultimately affect the oil production rate from the wellbore to surface facility. This condition can eventually lead to corrosion issues, increase cost of managing surface equipment such as pumps, tanks, etc. Failure to separate the oil and water mixture efficiently and effectively could result in problems such as overloading of surface equipment, increased cost of pumping wet crude, and corrosion problems.

Chemical de-emulsifiers (amine group) were added in varied proportions to crude oil emulsions in a production flow station in the Niger Delta area to enhance demulsification of the crude oil emulsion. Simulation tests were run on each of the factors influencing stability and results on how they can enhance demulsification of tight crude emulsion were obtained. The surface tension and viscosity of the tight crude oil emulsion considered reduced by two and one percent in the value respectively after de-emulsifier injection at a constant temperature and flow rate. An increment of one percent in the water composition was observed after de-emulsifier injection at a constant temperature and flow rate. This when matched against established electrical stability trendline, showed a decrease in the electrical stability of the emulsion formed as a result of an increase in water content.

Keywords: words: *emulsion; demulsifiers; demulsification; stability; virtual modelling; asphaltenes; amine; simulation; viscosity; water content, droplets; sensitivity*.

1. Introduction

As a definition, emulsion is a system where one liquid exists in a dispersed droplet from, within another relatively immiscible liquid. Emulsions may be found in cosmetics, drugs/ medicines, various food types, etc. Water droplet dispersed in the oil phase and termed as "water-in-oil" (W/O) and oil droplets dispersed in the water phase and termed as "oil-in-water" (O/W) emulsion are the two common emulsion types in oil production flow assurance. Also in existence is the multiple or complex emulsion types but are not a common occurrence in a production flow station. Emulsions have been of great interest to many in recent times because of the frequency of natural occurrence and the nature of the surface interactions.

Crude oil emulsions are complex and should be characterized as completely as possible. Droplet-size distribution, interfacial phenomena, and the nature of organic and inorganic components are important. The viscosity of the crude oil emulsion is affected by both the water content and droplet size distribution. The increase in aqueous phase of the emulsion leads to an increase in viscosity of emulsion which in turn aggravates flow of emulsion either at the sand phase or through the surface facilities. Stable water-in-oil emulsions have been generally found to exhibit high interfacial viscosity and/or elasticity modulus. Viscosity of crude oil emulsion was found to increase with increase in water and decreased with increase in speed of rotation of spindle when demulsifier is added [1-10].

In the oil industry, water-in-oil emulsions are more common, and as such the oil-in-water emulsions can sometimes be referred to as "reverse" emulsions.

Emulsion viscosities in most cases are greater than the viscosity of the oil and the water because emulsions often demonstrate non-Newtonian behavior. This non-Newtonian characteristic is a direct result of droplet crowding. A fluid by definition is considered a non-Newtonian fluid when its viscosity is a clear function of shear rate. Another important property, for demulsification purposes, is the interfacial viscosity, also defined as the viscosity of the fluid at the oil/water interface. As mentioned earlier above, water-in-oil emulsions form interfacial films that encapsulates the water droplets. These films help to stabilize the emulsion by lowering the interfacial tension (IFT) and increasing interfacial viscosity. These films end up reducing the rate of emulsion breakdown by retarding the rate of oil-film drainage during the coalescence of water droplets. High interfacial viscosity slows down the liquid drainage rate and thus has a stabilizing effect on the emulsion. Thus it can be concluded that oil-drainage rate depends on the interfacial shear viscosity and emulsion interfacial viscosity plays a very important role in demulsification.

1.1. Objective of study

With various problems encountered with the presence of emulsion in the system, (mostly tight emulsion) there is the need to find ways of controlling existence of emulsion, preventing or treating it appropriately when it is formed in the system. The objectives of this study are to:

1. Develop a simple protocol to simulate oil tight emulsion and use best modeling technique process for demulsification of tight emulsion (water-in-oil emulsion).
2. Examine/carry out sensitivity analysis on the factors affecting crude oil emulsion stability.

1.2. Background of study

A model approach was employed throughout this study to appreciate the simulation effect of de-emulsifier in de-stabilizing an invert water-in-oil tight emulsion from a chemical and mechanical standpoint. Analysis of simulation results was drawn from an already laboratory established trendline of an electrical property called Electrical Stability, ES measured with an electrical stability meter probe.

1.2.1. Electrical stability

When water is dispersed in oil as in water-in-oil emulsion, it is important to obtain the degree of emulsification precisely “tight” or “loose” emulsion, this enhances decision making as to optimally recommend the type and quantity of de-emulsifier to inject that will break or destabilize the emulsion formed. Conventionally in the laboratory, an electrical stability meter or probe is used to measure the emulsion stability in volts. Table 1 show the range and remarks on different electrical stability values.

Table 1. Range and remarks on different electrical stability values.

ES Value	Unit	Remarks
<400	Volts	Poor
400	Volts	Stable
>400	Volts	Tight

1.2.2. Relationship between ES and surface tension

Surface tension is the energy, or work required to increase the surface area of a liquid by a unit area due to their intermolecular forces. Measured in dyne/cm. Surface tension is an important factor in determining the emulsion stability of water-in-oil crude oil emulsion. High surface tension shows high emulsion stability while low surface tension shows low emulsion stable.

By default, the flow station at node LP1/2 exhibits a high surface tension value of 29.92 dyne/cm at a surface temperature of 100ºF thereby confirming the stability of the emulsion formed. Also it is good to know that the surface tension decrease with increase in temperature of the process fluid as many companies will install heaters to break the emulsions formed.

1.2.3. Relationship between ES and viscosity

Viscosity is an important fluid property when analyzing liquid behavior and fluid motion near solid boundaries. Viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress and tensile stress and is measured in centipoise (cP). Electrical stability as it relates viscosity, increases with increasing viscosity. This is due to the fact that the mobility of the "dispersed water" will be greatly reduced, thereby making it difficult for the water molecules to coalesce and come out of solution under gravity.

By default, the flow station model at node LP1/2 exhibits a substantial viscosity value of 4.476 cP at a surface temperature of 100ºF thereby confirming the stability of the emulsion formed. Also, the effect of the temperature of the process fluid to its viscosity will be observed in the model.

1.2.4. Relationship between ES and water content

Water is often present in crude oil as emulsified salt water. The presence of water is a typical feature of all known petroleum and natural gas deposits. Gases and solids in crude are relatively easy to remove from hydrocarbon fluids. Formation water (also referred to as connate water or produced water) is harder to separate out, apart from a more or less low percentage that naturally separates from the crude (indicated as free water: FW). The water that does not separate naturally from the crude in which it is present in the form of emulsion (BS: Base Settlement) and can be removed by chemical products called de-emulsifiers. The total water content of crude is generally indicated with the term Water Cut (WC).

Thus, WC = FW + BS

Water content in crude is a major factor that determines the Electrical Stability of water-in-crude oil emulsion and also acts as a solid when dissolved in synthetic oil by giving it buoyancy. Directly speaking, increasing water content reduces the emulsification action thereby reducing the electrical stability value. Also it reduces the viscosity of the crude thereby affirming the reduction in emulsion stability. For the purpose of this simulation, we expect increased water content after de-emulsifier injection.

2. Materials and methods – virtual experimental method

A virtual experiment was conducted using commercial process simulation software; with compositional analysis of default crude oil properties which delineates tight emulsion prone crude oil. Other relevant materials include the polymer (decylamine) de-emulsifier reaction set, C_{7+} and de-emulsifier characterization set.

The experimental methods are divided into three;

1. Virtual modelling of a tight emulsion process plant
2. Emulsion preparation
3. Simulation and sensitivity runs

2.1. Virtual experimental aim

The aim of this virtual experiment is to show the effectiveness of the chemical de-emulsifiers listed above as capable of breaking oil/water emulsions for improved oil recovery operations.

2.2. Virtual modelling of tight emulsion process plant crude oil properties

Compositional analysis, the physical and chemical properties of crude oil used for the experiment such as molar concentrations, API gravity, viscosity, the asphaltene content were obtained and used to build the model.

2.3. Model production system description

Wells fluids flow through their respective flow lines come into the flow station and enter the Inlet manifold/skids. The wells come in at different pressure regimes (HP at about 10-12 barg and LP at about 2.5-3.5 barg). The HP wells flow into the HP header while the LP wells flow into the LP headers. The test headers are used when a well is to be tested.

Fluid directed to the HP header goes into the HP separator, set at 10.0 barg, where it is flashed. Separated liquid as a result of this flash leaves the HP separator through the bottom and goes into an LP intermediate header which then carries this liquid into the LP1 separator, set at 3.0 bar for further degassing. Fluid directed to the LP header goes into the LP separators, set at about 3.5 bar. Liquid from the LP separators flows into the surge vessels, set at about 0.2 bar, for final stabilization (degassing).

The liquid is then pumped by reciprocating pumps at about 21 bar into the delivery line to Bonny Terminal via TNP for final processing.

Associated gas separated from the HP and LP separators are sent to the AGG plant through the HP and LP gas lines for further processing. Residual gas further separated at the surge vessels is sent to the flare knockout vessel and then to the flare. Liquid from the FLKO is pumped back to the surge vessel.

2.4. Simulation set-up

Data used for the simulation study was sourced from the following flow station as built drawings, flow station equipment data sheet, PVT reports, production chemistry laboratory data and surveillance data from site visit. A quality assurance and quality control analysis were performed on the PVT data gathered to further validate the data and determine the degree of accuracy using the mole balance plot.

This section describes the approach taken to model the crude oil stabilization station as it is on the field, this however allows the engineer to run different de-emulsification scenarios and make optimum decisions.

Basic equipment's used for the simulation includes separator, surge vessel, mixer and valve. This equipment's were added to the PFD (a graphical representation of the topology of a simulation case) environment using the methods as described.

To enable the demulsifier to be effective, it must contact the emulsion and the oil/water interface. Agitation and mixing is required to provide an opportunity for the chemical to mix well with the emulsion. This agitation paves the way for droplet coalescence; which is the point at which the demulsifier is added to the mixture–this is an important phase of the process. The first operation installed in the model is a mixer used to combine the reservoir fluid stream and the de-emulsifier stream. As in most commercial tools installing a mixer can be accomplished by a number of ways. Also separators where installed in the model to separate the gas and liquid phases. Surge vessels were added to the model to further define the direction of the gas and liquid streams and to control the flow of the two phases. Then pressure valves were added to the model to control the pressure of the inlet and outlet streams in the model.

2.5. Emulsion preparation

2.5.1. Asphaltenes characterization

Asphaltenes characterization was carried out in the compositional analysis. This characterization is important to determine the fraction of Asphaltenes in the reservoir fluid. Asphaltenes compositions are arranged in ascending order in w/w % from the component of highest abundance to that of lowest abundance ranging from carbon, hydrogen, oxygen, nitrogen and sulfur. Characterization was carried out in all these compositions of Asphaltenes which includes oxygen, sulfur, carbon, nitrogen, hydrogen, traces of vanadium and nickel in ascending order. In this context, the asphaltenes characterization is defined as the determination of the critical temperatures, critical pressure, acentric factor and interaction parameters of the asphaltenes component. Also performed in the compositional analysis is the C_{7+} characterization. In order to have a truly representative model, one must characterize the C_{7+} fraction of the reservoir fluid. Characterization can be defined here as the determination of the critical temperatures, critical pressure, acentric factor and interaction parameters. In this study, C_{7+} was characterized in the petroleum fraction sub-section using the boiling point, molecular weight and specific gravity as input parameter. The composition is then added to the main composition and an amount entered before calculating the critical properties and acentric factor

2.5.2. De-emulsifier characterization

De-emulsifier characterization was also performed in the compositional analysis. De-emulsifier characterization can be defined as the determination of the critical temperatures, critical pressure, acentric factor and interaction parameters. In this study, de-emulsifier was characterized in the petroleum fraction sub-section using the boiling point, molecular weight and specific gravity as input parameter. The composition is then added to the main composition and an amount entered before calculating the critical properties and acentric factor. Amine group de-emulsifier (decyl-amine) was used for this process model

3. Simulation test and results

3.1. Demulsification simulation 1 test results:

Demulsification simulation number one(#1) was run to know the effect of injecting decyl-amine de-emulsifier on the chemical and mechanical properties of the water-in-oil tight emulsion. Results gotten from this simulation were interpreted based on the already laboratory established trends from de-emulsification bottle test results. Demulsification simulation test two (#2) were run to know the effect of increasing de-emulsifier concentration (from 0 ppm to 20 ppm) of decyl-amine de-emulsifier in breaking the tight crude oil emulsion. Results gotten from this simulation were interpreted same for the test number one.

Increased temperature effect on physical properties that delineated tight crude oil emulsion was carefully studied and observed from this sensitivity simulation run. Simulations were run for different injection temperatures ranging from 20°F to 120°F. De-emulsification performance was evaluated from a chemical and mechanical standpoint.

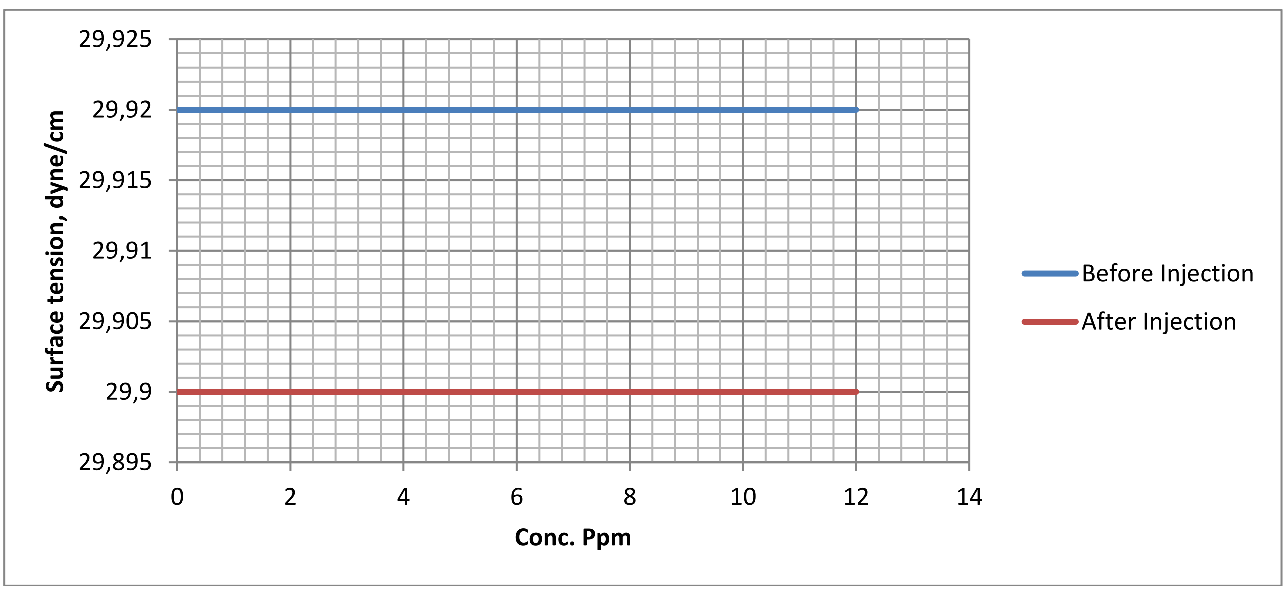

Figure 1. Demulsification Simulation #1: Effect on surface tension

The result simulation interface shows that there was a 2% reduction in the value of surface tension after de-emulsifier injection at constant temperature and flow rate. This when matched against the electrical stability trendline established above delineates that there was a decrease in the stability of the emulsion formed as decrease in surface tension leads to a decrease in electrical stability.

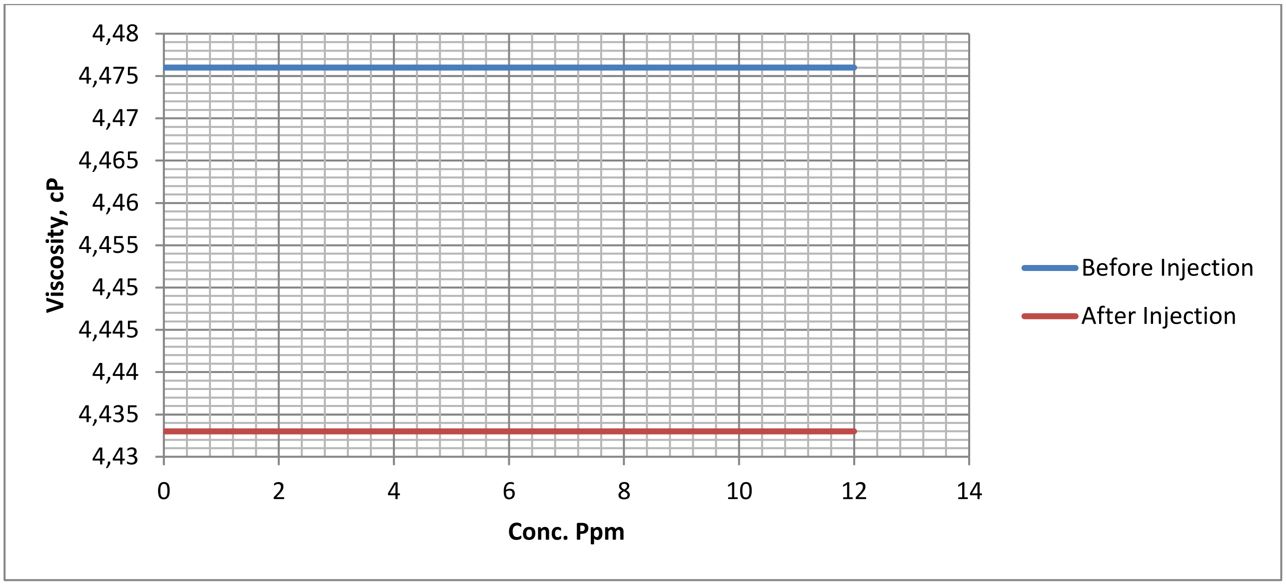

Figure 2. Demulsification Simulation #1: Effect on viscosity

The result simulation interface shows that there was a 1% reduction in the value of viscosity after de-emulsifier injection at constant temperature and flow rate. This when matched against the electrical stability trendline established above delineates that there was a decrease in the stability of the emulsion formed as decrease in viscosity leads to a decrease in electrical stability.

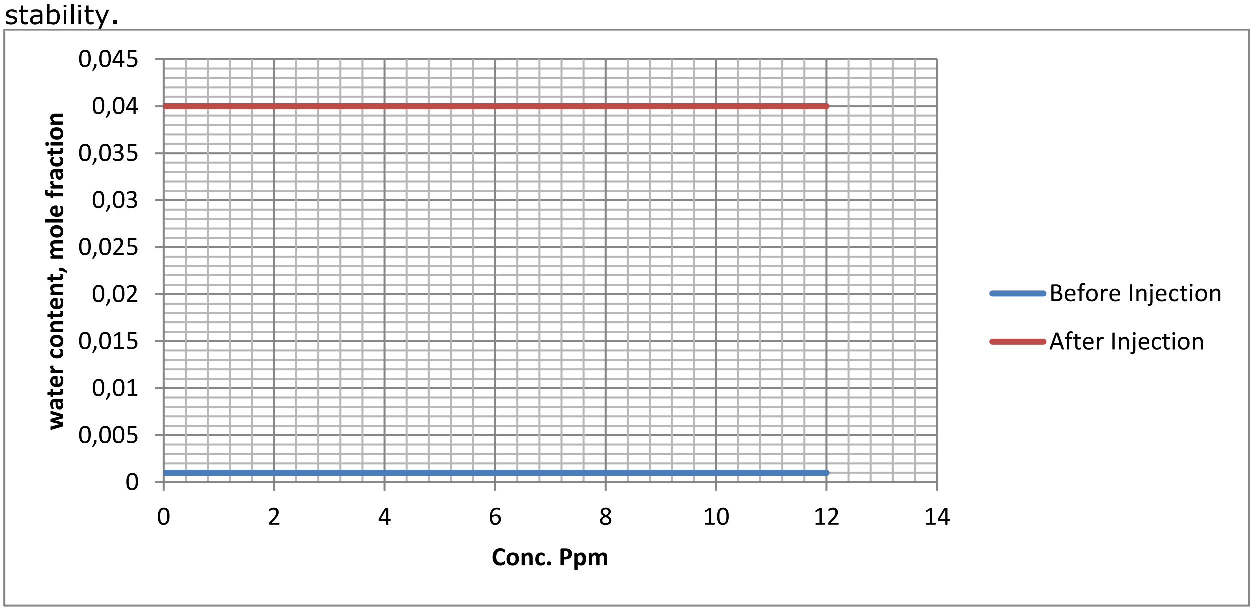

Figure 3. Demulsification Simulation #1: Effect on water content

Result simulation interface shows that there was a 1% increment in the water composition after de-emulsifier injection at constant temperature and flow rate. This when matched against the electrical stability trendline established above delineates that there was a decrease in the stability of the emulsion formed as increase in water content leads to a decrease in electrical stability.

4. Discussions of results

4.1. Sensitivity rest analysis results

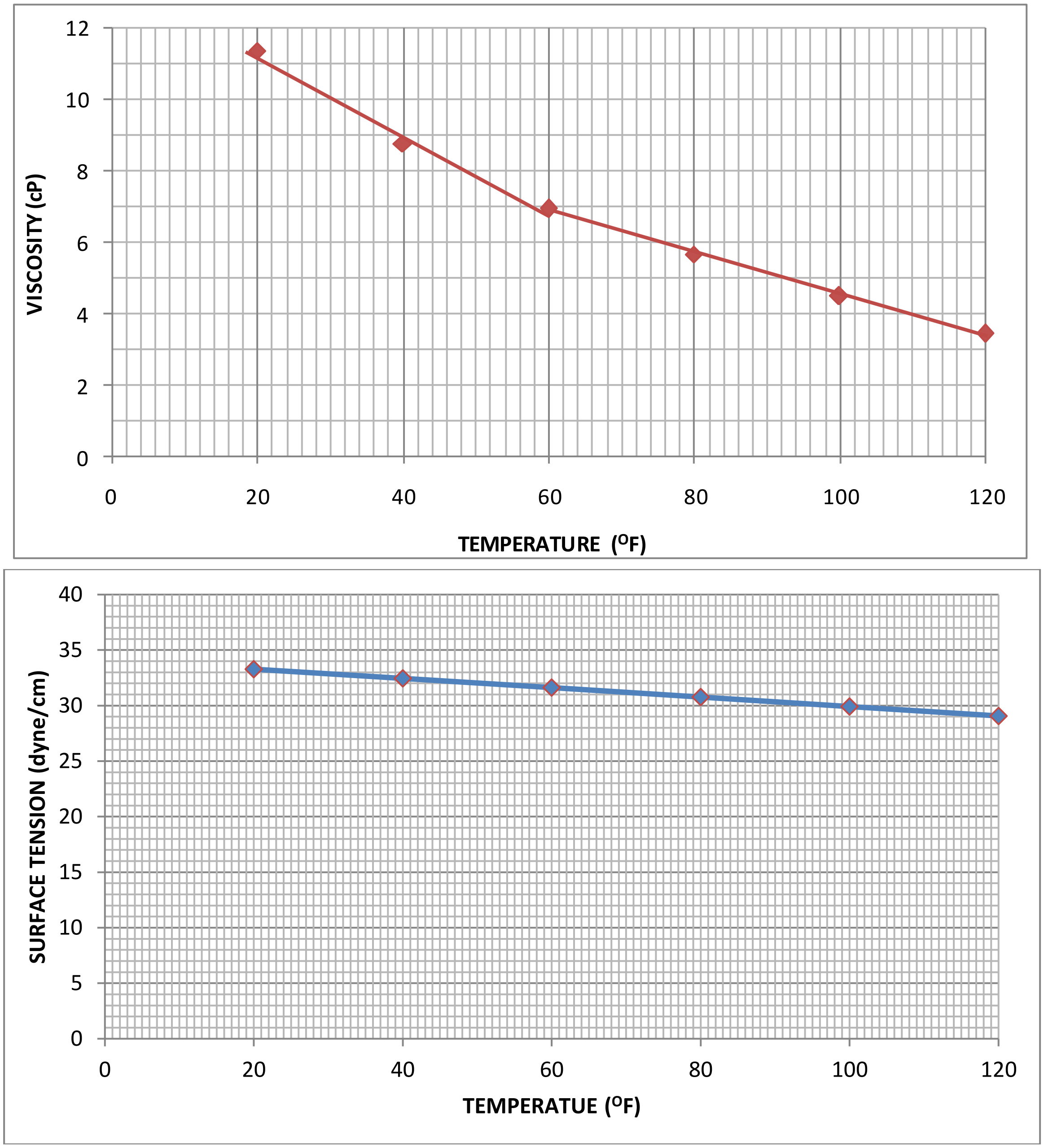

Figure 4. Effect of on viscosity and surface tension

From figure 4. it can be deduced that operating temperature of de-emulsification process should be optimally maintained as this greatly affects the performance of the de-emulsifiers. The optimal temperature of any de-emulsification process must be determined. Temperatures above the optimal temperatures may yield good, but not optimal results. For our case study above, the optimal operating temperature range is 60-80°F – temperatures above this range may not be cost effective.

5. Conclusion and recommendation

The role of de-emulsifier in emulsion breaking cannot be over emphasized in the sense that, de-emulsifier plays an important role in oil production process by preventing or reducing emulsion stability thereby saving cost of production-which is of economic benefit. Understanding the normal system processes is important however knowledge of the process when there is a change in the condition of the system is the real challenge in any operating system. Knowledge of what to expect from these processes when a change occurs in certain scenarios can be simulated into the plant operating philosophy, ensuring shorter downtime and generally higher profitability for a given system.

Selection of the right demulsifiers is critical to the success of a production plant and virtual simulation can enhance the performance and profitability of any given system

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