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The Static Laboratory Testing for Fracturing Fluid Optimization

Boni Swadesi[1], Ahmad Sobri[2], Dewi Asmorowati[3], Mia Ferian Helmy[4], Ahmad Azhar[5], Roiduz Zumar[6], Susanti Rina Nugraheni[7]

[1, 2, 3, 4, 5, 6] Petroleum Engineering Department, UPN Veteran Yogyakarta, Indonesia
[7] Chemical Engineering Department, UPN Veteran Yogyakarta, Indonesia

Abstract

Hydraulic fracturing operation is the common method to stimulate an oil well in order to make the permeability around the well become higher by injecting a mixing of fracturing fluid and proppant. Hopefully, this higher permeability can contribute to increase the production of oil and/or gas. The fundamental laboratory assessment of fracturing fluid as a part of injected component is important to be conducted before field scale implementation. One of the fundamental assessment is the static laboratory testing. In this test, the fracturing fluid sample is measured to obtain the data about its properties such as water quality, rheology, crown time and breaking time. These properties give important role to calculate the performance of the hydraulic fracturing field scale operation would be. In this research, we conducted the static laboratory testing for fracturing fluid in sensitivity of concentration which are 35, 40 and 45 systems. Every concentration have been measured its properties in order to compare each other to evaluate and select best fracturing fluid candidate for field scale application.

Keywords: Hydraulic Fracturing, Static Laboratory Testing, Fracturing Fluid, Fluid Properties

INTRODUCTION

The decline of oil production due to the very small permeability of reservoir rocks and the effect skin factor gives impact on non-optimal well productivity. One of the method to increase oil production is hydraulic fracturing. Hydraulic fracturing is a well stimulation activity by injecting pressurized viscous fluids with certain chemicals and propane so that the reservoir rock fractures in order to get the higher permeability of reservoir layer especially pay zone. With the increase in the permeability of the pay zone, it is expected that the production rate of the well can increase.

In the implementation of hydraulic fracturing, viscous fluid with base-gel (polymer) is injected in purpose to bring propant into the pay zone. The high pressure is applied in this operation for creating fractures in the formation. In hydraulic fracturing activities, knowing the behavior and properties of the fluid will greatly affect the calculation of fluid mechanics and fracturing geometry which will then also be very influential in the calculation of the field implementation plan. This is one of the fundamental assessments to evaluate the fracturing fluid performance by conducting experimental static laboratory test.

LITERATURE REVIEW

Fracturing Fluid Rheology

Rheological testing is a viscosity test to see the performance of polymers with a certain sensitivity. This study conducted a rheological test of differences in shear rates, differences in concentration and differences in fluid design. Fracture fluids will have high shear rates when in tubing, perforations, and through fractures. The highest shear rate will occur in perforations and fractures. The baseline HP/HT test will be carried out at a high shear rate of 100 sec-1 as an industry standard to determine fluid stability at a certain time for several fluids with many iterations (Gondalia, et al., 2019). Baseline tests were carried out with a Brookfield LVDV3T Spindle CV40 Viscosimeter. The working principle of this tool is to measure the ability of the solution to withstand a rotation (shear rate), this rotation will also form a velocity

Corresponding author:
boniswadesi@upnyk.ac.id
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gradient (Shear Stress) so that this tool will read the torque from the solution. Torque readings from this solution will be used to calculate the polymer viscosity in each condition.

Fluids can be classified based on their behavior to shear stress (τ) and shear rate (γ). There are 3 types of fluids, namely Newtonian fluids, Bingham Plastics, and Power Laws. Newtonian Fluid is a type of fluid that has a constant (linear) relationship between shear stress and shear rate, so its viscosity is not affected by shear rate and shear stress but is influenced by temperature. Bingham Plastic and Power Law Fluids are non-Newtonian fluids whose viscosity is affected by changes in shear stress, shear rate, and temperature. It is depicted in a graph of the type of fluid with its relationship to shear stress and shear rate in **Figure 1.**

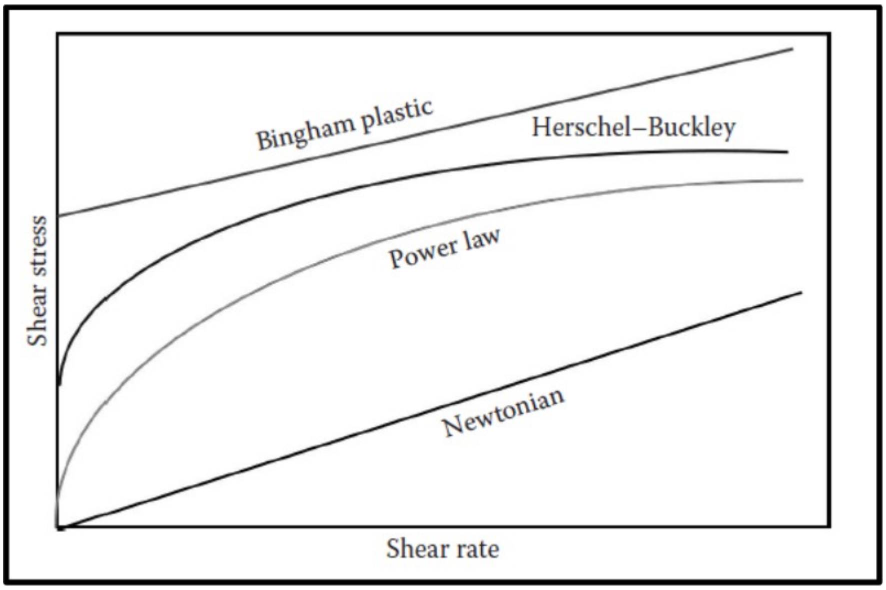

Figure 1.
Relationship of Shear Rate vs Shear Stress
(Smith & Montgomery, 2015)

Crown Time

The crosslinker will react with the linear polymer which will be connected to each other between the molecules resulting in a dynamic increase in viscosity. The speed of crosslinking between polymer molecules must be determined or tested so that friction pressure loss and shear degradation of the crosslinked fluid can be avoided (Smith & Montgomery, 2015).

Batchtop test (mixing fluid chemicals in the laboratory per concentration design was carried out. In this trial, Crown Time was measured where the vortex closure time was measured when a crossliked fluid occurred. Usually, two kinds of vortex closure time measurements were taken in the mixing jar. When the linear gel vortex started flat is called VCT1 (when the crosslinking process begins; VCT: Vortex Closure Time). When crosslinking is complete, the vortex will be completely closed and is called VCT2 (Gondalia, et al., 2019).

Break Time

After the cross-linked fluid occurs, the break time test is then carried out. The purpose of the break time is to determine the time required for the polymer bond to be degraded so that the polymer in the fracture can come out and not cause a residual effect on the fracture and so that there is no polymer break that is too fast so that the viscosity of the fluid drops prematurely which causes the fracture to not form as planned. Break time is normally defined as the point where the gel drops to 10 cp or less. (Smith, M. B., & Montgomery, C. T, 2015)

RESEARCH METHODOLOGY

Static test is experimental laboratory testing for measuring the fracturing fluid properties in order to evaluate its performance before field scale implementation. Fracturing fluid properties which can be obtained by static test are water quality, rheology, crown time and breaking time. It is really important to obtain the properties for ensuring the successfully hydraulic fracturing job. From this test, it is possible to get the most optimum design of fracturing fluid which is compatible to be applied on existing field condition.

The static test has several instruments such as litmus paper, colorimetric titration, hydrometer, Candler 3500 / Fann 35 rheometer, Candler 5550 HPHT viscosimeter, warring blender, stopwatch, water bath, digital scales. The explanation of each testing are written below:

Water Quality Test

The water quality test in the static test is needed to determine the content and quality of the water that will be used in mixing the fracturing fluid so that the quality of the fracturing fluid can be maximized according to the required design. In testing the quality of water to be used usually include pH, water hardness, iron content ($Fe2+$), and bicarbonate ions. A good pH of water for making facturing fluid is between 6 and 8 so it is not too acidic or alkaline (tends to be neutral). Water hardness is the level of minerals contained in water such as Ca, Mg, and other metal ions. Good water hardness to use does not exceed 500 ppm. The iron content of $Fe2+$ does not exceed 10 ppm because excess iron content will cause premature, over-crosslink, and will cause premature break fluid and decrease crosslink fluid quality during the pumping process. The bicarbonate ion content does not exceed 1000 ppm because if it is more than that, the HCl will be acidified until it gets a pH of 3.5 or 4, then the pH is reset with caustic to pH 6-8, the volume of HCL and the caustic weight are calculated when treating in 1 liter of water sample.

Rheological Testing

Rheological testing is a viscosity test to see the performance of polymers with a certain sensitivity. This study conducted a rheological test of differences in shear rates, differences in concentration and differences in fluid design. Fracture fluids will have high shear rates when in tubing, perforations, and through fractures. The highest shear rate will occur in perforations and fractures. The baseline HP/HT test will be carried out at a high shear rate of 100 sec-1 as an industry standard to determine fluid stability at a certain time for several fluids with many iterations (Gondalia, et al., 2019). Baseline tests were carried out with a Brookfield LVDV3T Spindle CV40 Viscosimeter. The working principle of this tool is to measure the ability of the solution to withstand a rotation (shear rate), this rotation will also form a velocity gradient (Shear Stress) so that this tool will read the torque from the solution. Torque readings from this solution will be used to calculate the viscosity of the polymer in each condition.

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In the SOP set in the laboratory, 300 ml of the sample will be put into a blender jar then blended with a rotational speed of 1000-1500 rpm until a vortex rotation is seen. Add a number of buffers and breakers according to the design concentration and then check the pH. After the optimal pH is then added crosslink agent according to the design concentration. When adding a crosslink agent, the time when the vortex closes is recorded as "Vortex Closure Time". When the fluid rotation forms a convex shape like a hat then turn off the blender and record the time on the stopwatch as "Crown Time". Move the crosslink fluid from one glass to another when it looks unbroken (lips), record it as “Release Time”.

Break Time

After the cross-linked fluid occurs, the break time test is then carried out. The purpose of the break time is to determine the time required for the polymer bond to be degraded so that the polymer in the fracture can come out and not cause a residual effect on the fracture and so that there is no polymer break that is too fast so that the viscosity of the fluid drops prematurely which causes the fracture to not form as planned.

In the laboratory SOP, the crosslinked polymer fluid that has been formed is put into a bottle and then the bottle is put in a water bath whose temperature has been adjusted according to reservoir conditions. Then checks are carried out periodically until the fluid becomes watery (when the polymer bonds have broken) and the time is recorded until these conditions are also checked for pH after the break.

FINDING AND DISCUSSION

Based on the static laboratory testing, the properties of fracturing fluid are obtained. The fracturing fluid measured in this research have three different concentration, which are 35, 40 and 45 system. The rheological property of 35 system fracturing fluid is shown by **Table 1.**

Table 1. Rheological Propertiy of 35 system fracturing fluid

RPM	600	300	200	100	6	3
Viscosity, cp	40	31	24	16	3	2

This 35 system fracturing fluid is classified as non-newtonian fluid. Based on **Table 1**, viscosity of the fluid is varied by the changing of RPM. It is the indicator that the fluid is non consistent by the RPM variation. This inconsistent of viscosity is the behaviour of non-newtonian fluid. It also has recorded that 35 system fracturing fluid has pH value 6.

The next fracturing fluid which has been measured is 40 system. The rheological property of 40 system fracturing fluid is shown by **Table 2.** The crown time and break time measurement are also conducted in this 40 system fracturing fluid. The properties can be seen in **Table 3.**

Table 2. Rheological Propertiy of 40 system fracturing fluid

RPM	600	300	200	100	6	3
Viscosity,cp	48	37	30	20	4	2

Table 3. Crosslinker and Breaker Perfomance of 40 system fracturing fluid

Properties	Value	Unit
pH	6	
On Fly	404420	
Crown Time	12	sec
Release Time	15	sec
Break Time	2	hours @80 degF
Break Fluid Viscosity	10	cp

The last fracturing fluid which has been measured is 45 system. The rheological property of 45 system fracturing fluid is shown by **Table 4.** The crown time and break time measurement are also conducted in this 40 system fracturing fluid. The properties can be seen in **Table 5.**

Table 4. Rheological Propertiy of 45 system fracturing fluid

RPM	600	300	200	100	6	3
Viscosty, cp	57	42	35	24	7	4

Table 5. Crosslinker and Breaker Perfomance of 45 system fracturing fluid

Properties	Value	Unit
pH	6	
On Fly	454420	
Crown Time	12	sec
Release Time	16	sec
Break Time	2	hours @80 degF
Break Fluid Viscosity	12	cp

CONCLUSION AND FURTHER RESEARCH

The static laboratory test of three different fluid result is water quality to be used, fracturing fluid rheology, fracturing fluid pH, crown time, release time, break time, and break fluid viscosity. Each fracturing fluid can shows different properties. Based on the experiment by using 35 system, 40 system, and 45 system shows the viscosity increased by the higher the concentration.

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