JOURNAL OF PETROLEUM AND GEOTHERMAL TECHNOLOGY
ISSN: 2723-0988, e-ISSN: 2723-1496
Vol.4 No. 1 2023

Evaluation of Propellant/Stimgun Stimulation Works Using Geomechanical Analysis Based on Well Logging Data in an Effort to Increase Production at the EYP-211 YNK Structure Well in the Jambi Field

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ABSTRACT

The oil production flow rate of the EYP-211 well is relatively small, only 12.75 BOPD. The small fluid flow rate is caused by the small formation permeability which is only 2.1 mD. Currently the EYP-211 well has been stimulated with Propellant/Stimgun, but not all of the formation layers can be carried out by Stimgun work so that it is necessary to evaluate it with Geomechanical analysis to determine the success of the stimulation work by calculating the Poisson's ratio and Young's modulus which will be analyzed based on well-logging data.

Based on the results of the brittleness index and fracability index analysis, the EYP-211 well is recommended to be stimulated at a depth of 632.92 m to 635.46 m. Stimgun work on the EYP-211 well resulted in a fracture with an average fracture width of 0.02035 in, a fracture height of 9.81 ft and a fracture length of 481.09 ft. The formation permeability increased from 2.1 mD to 14.07 mD due to fractures produced by the stimulus. The flow rate of oil production in the EYP-211 well increased from 12.75 bopd to 140 bopd due to the increased permeability generated by the fracture.

Keywords: stimgun; propellant, fracability index, brittleness index, fracture

I. INTRODUCTION

The EYP-211 well is an oil producing well located in the Yankee field. The oil production flow rate of the EYP-211 well is relatively small, only 12.75 BOPD. The small fluid flow rate is caused by the small formation permeability which is only 2.1 mD. The well water cut is already above 90% making the flow rate of oil production small and dominated by formation water. Therefore, in the EYP-211 well, it is necessary to carry out stimulation work.

Currently the EYP-211 well has been stimulated with Propellant/Stimgun, but not all of the formation layers can be carried out by Stimgun work so that it is necessary to evaluate it with Geomechanical analysis to determine the success of the stimulation work by calculating the Poisson's ratio and Young's modulus which will be analyzed based on well-logging data. From the evaluation results, the brittleness index and fracability index will be obtained so that the perforation point is right so that it gets a higher fracture success rate in the hydrocarbon zone.

II. METHODS

The evaluation begins by collecting data in the form of rock characteristics & well logging data such as Resistivity Log, Sonic Log, Density Log, SP Log and Neutron Porosity Log then calculating and analyzing rock mechanical properties such as Poisson's ratio and Young's modulus, brittleness index and fracability index. The fracture model analysis was made using Drillwork and FRACade software and the exact location of the Stimgun perforation point. Then also obtained the appropriate fracture geometry and an increase in permeability. It is necessary to evaluate the IPR data before and after the Stimgun work is carried out to find out the final result of whether the Stimgun work has succeeded in increasing the production flow rate in the formation optimally.

III. RESULTS AND DISCUSSION

3.1. Result

From the results of the calculation of the Poisson's ratio starting from a depth of 446 m to a depth of 650 m, the average value of the Poisson's ratio is 0.396. From the calculation results of the Young's modulus starting from a depth of 446 m to a depth of 650 m, the average value of Young's modulus is 7.75 Gpa.

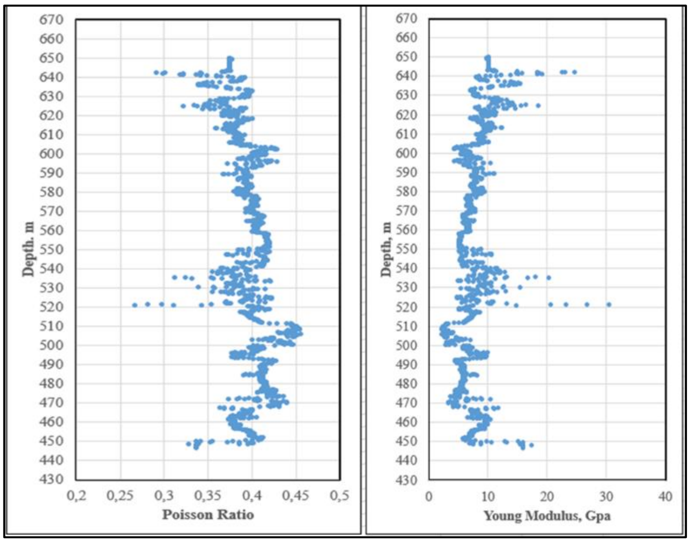

Figure 1. Poisson Ratio and Young Modulus Ratio Distribution

Poisson's ratio can be calculated using **Equation 1**

$$v = 1/2\frac{(Vp^2 - 2Vs^2)}{(Vp^2 - Vs^2)} \quad (1)$$

Young's modulus can be calculated using **Equation 2**

$$E = \rho Vs^2\frac{(3Vp^2 - 4Vs^2)}{(Vp^2 - Vs^2)} \quad (2)$$

The determination of this Overburden stress will be the basis for all subsequent analysis stages. Overburden stress can be calculated integration of the density log, the results of the calculation of the overburden gradient can be seen in the image below :

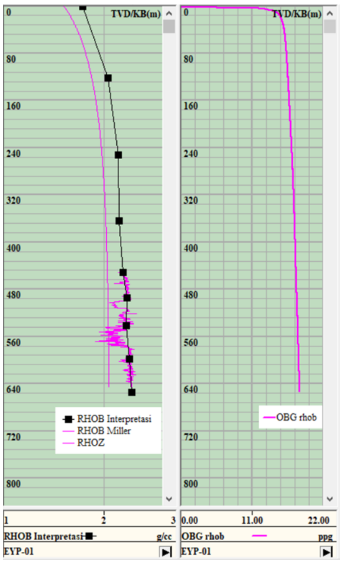

Figure 2. Density Log EYP-211

JOURNAL OF PETROLEUM AND GEOTHERMAL TECHNOLOGY
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Calculation of the overburden stress gradient at a depth of 601 m or 1971,784 ft with a density of 17,2442 ppg obtained 1870,750 psi.

After calculating the overburden gradient, the next step is to determine the pore pressure. The method used in calculating Pore Pressure in Drillwork Predict using Eaton Method. Pore Pressure data processing using Sonic logs can be estimated using the Eaton method. Eaton was the first to introduce a fudge factor in the form of the Eaton Exponent, where the value of the Eaton Exponent can be changed. To calculate the Pore Pressure on the Sonic log, using the Eaton method, you must first know the parameters such as the sonic log, normal pore pressure gradient, overburden gradient and normal Sonic trend. It is assumed that the EYP-211 well for normal pressure gradient is 0.433 psi/ft (fresh water) or equivalent to 8.33 ppg. The pore pressure result is 918,34 psi.

Pore Pressure can be calculated using **Equation 3**

$$PP = \mathrm{OP} - (\mathrm{OP} - \mathrm{Pn}) \left(\frac{\Delta t\ normal}{\Delta t\ observed}\right)^3 \quad (3)$$

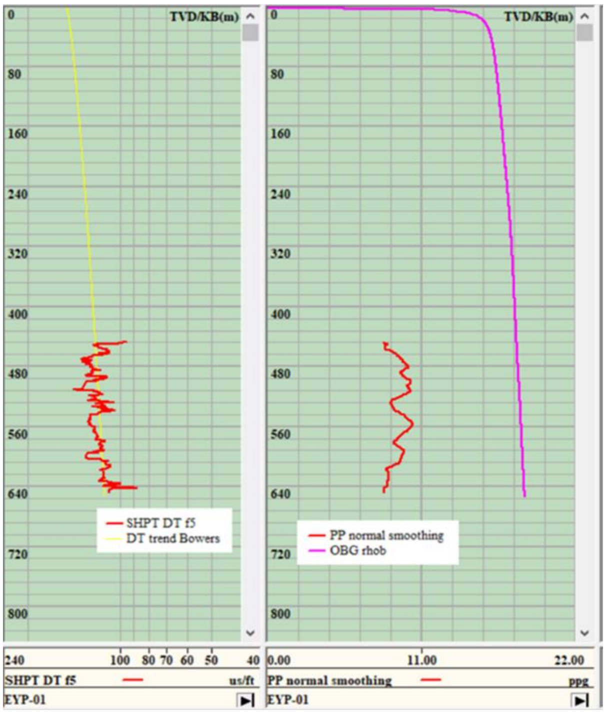

Figure 3. Pore Pressure EYP-211 by Sonic Log

The effect of drawing the normal Sonic trend line on the Sonic log greatly affects the value of the pore pressure itself, where the value below the normal Sonic trend is an abnormal zone (overpressure) while the value above the normal Sonic trend is a subnormal zone.

After calculating the pore pressure, the next step is to determine the minimum horizontal stress and maximum horizontal stress. Before calculating the Shmin and Shmax values, we must first determine the type of fault that occurs in the EYP-211 well regional. According to Anderson's classification theory, faults are divided into 3, namely normal faults, flat faults and rising faults. Where the latest research data from geologists shows that in the EYP-211 well the type of fault that occurs is a strike-slip fault. Calculation of the minimum horizontal stress with equation 4 at a depth of 602 m or 1975.72 ft. The Shmin result is 1517,21 psi.

Shmin can be calculated using **Equation 4**

$$S_{hmin} = \frac{v}{(1 - v)} (Op - Pp) + Pp \quad (4)$$

The minimum horizontal stress value is the smallest of the 3 existing stresses (Obg, Shmin, Shmax) so Shmin can be assumed as the fracture pressure. Calculation of maximum horizontal stress with equation 5 at a depth of 602 m or 1975.72 ft. Because the type of fault that occurs in the EYP-211 well is a strike-slip fault, according to Anderson the value of k used is 1.2. The Shmax result is 1948,94 psi.

Shmax can be calculated using **Equation 5**

$$S_{hmax} = S_{hmin} + k\,(Op - S_{hmin}) \qquad (5)$$

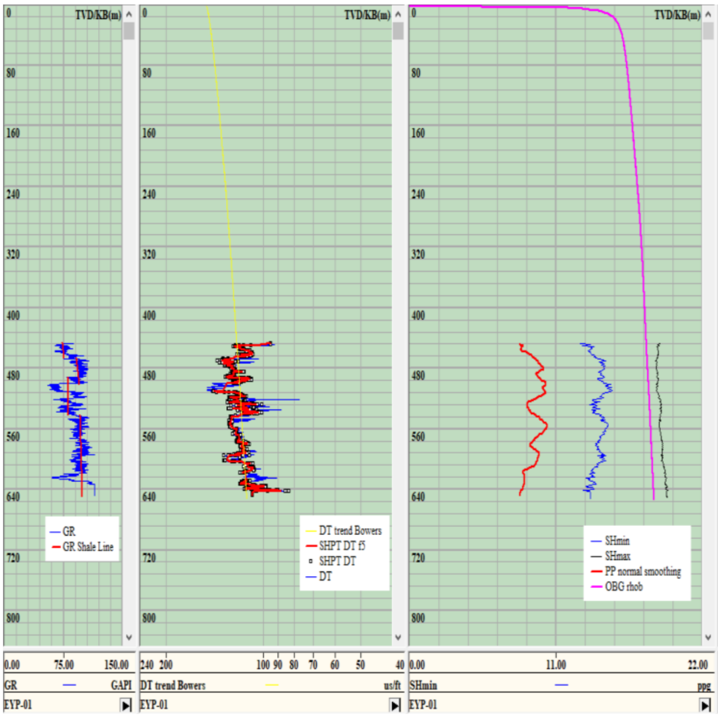

Figure 4. Result of Minimum Horizontal Stress and Maximum Horizontal Stress

The initial design starts from the selection of the prospect zone to be fractured, in the selection of the prospect zone the parameters that become the reference are the brittleness index and fracability index obtained based on the mechanical properties of the rock (Poisson's ratio and Young's modulus), the higher the value, the better the fracture formed. and stress contrast obtained based on the minimum horizontal stress difference at each depth.

Table 1. Brittleness index

Depth, m	*Brittleness index,* fraction	*Depth*, m	*Brittleness index*, fraction
446	0,557701692	550	0,300941657
450	0,629461562	560	0,210101601
460	0,426141829	570	0,227757877
470	0,19967604	580	0,212454641
480	0,264300456	590	0,278740213
490	0,230474553	600	0,188777361
500	0,225620652	610	0,291449098
510	0,015537273	620	0,395474173
520	0,192957221	630	0,247850608
530	0,226502658	640	0,286881508
540	0,313016508	650	0,351094117

The Brittleness index is a combination of Poisson's ratio and Young's modulus. The calculation of brittleness is carried out using the Grieser and Bray (2007) method based on Poisson's ratio and Young's modulus data. The following is the calculation of the brittleness index average at a depth of 600 m or 1968,5 ft with = 0.409, max = 0.454, min = 0.265, E = 6.05, Emax = 30.38 Gpa and Emin = 2.21 Gpa. Then a complete calculation of the brittleness index is carried out at a depth of 446 - 650 m. The results of the brittleness index calculation are shown in the table 1.

Fracability is defined as a measure of the ease with which a formation can be fractured. Fracability is determined by the method proposed by Jin et al (2014) in which the fracability value can be determined based on the brittleness index and young's modulus parameters. The following is the calculation of the fracability index at a depth of 600 m or 1968,5 ft with a value of BI = 0.188 fraction, BImax = 1, BImin = 0, E = 6.05 Gpa, Emax = 30.38 Gpa and Emin = 2.21 Gpa.

Then the complete calculation of the fracability index is carried out at a depth of 446 - 650 m. The results of the calculation of the fracability index are shown in Table 2

Table 2. Fracability Index

Depth, m	*Fracability index, fraction*	*Depth, m*	*Fracability index, fraction*
446	0,585813478	550	0,533989377
450	0,5865673	560	0,527994052
460	0,585106039	570	0,52941251
470	0,566041175	580	0,534467872
480	0,573496136	590	0,532815315
490	0,524318883	600	0,526108623
500	0,527449391	610	0,533509553
510	0,502874826	620	0,537053467
520	0,526493322	630	0,5308742
530	0,535250329	640	0,53326692
540	0,53455264	650	0,535992769

Based on the analysis of the brittleness index parameter which was analyzed based on Table 1, the fracability index which was analyzed based on Table 2, at a depth of 446 m to 650 m, the prospect zone based on the geomechanical parameters of the Air Benakat Formation was found at a depth of 632.92 m – 635.36 m as shown below. which can be seen in Figure 5.9. prospect zones based on geomechanical parameters are marked with black lines, namely the depth of 632.90 m and 635.36 m. Figure 5.9. shows the results of the brittleness index and fracability index plots at a depth of 632.92 m – 635.36 m.

Based on table 3, the parameters of the prospect zone are obtained with a brittleness index value of 0.54 fractions classified as brittle according to Altamar & Marfurt (2014) with a minimum of 0.48 fractions and a fracability index of 0.56 fractions classified as frackable according to Jin et al. 2014) with a minimum value of 0.55 fractions. So, based on geomechanical analysis and interpretation of well logging depth of 634 m – 638 m, hydraulic fracturing was performed.

Table 3. Prospect Zone

Kedalaman	*632,92 – 635,36*	*m*
Height	2,43	m
Brittleness index	0,54	Fraksi
Fracability index	0,56	Fraksi
Poisson’s ratio	0,35	
Young’s modulus	14,03	Gpa

The selection of fracturing fluid used is based on the characteristics of the reservoir so that fracturing runs safely, optimally and does not cause damage to the formation around the wellbore. Well EYP-211 has a B/600 layer as a productive zone containing a light oil reservoir with sandstone lithology. Layer B-600 with an average permeability of 2.1 mD with a reservoir pressure of 853 psia and has a reservoir temperature of 129.80 oF. The fluid injected into the EYP-211 well is a fracturing fluid with type BaseFluid-J6080(0.25)+ B244(0.25).

Table 4. Fracture Fluid Properties

Fluid Properties	*Value*	*Unit*
Name	BaseFluid-J6080(0.25)+ B244(0.25)	
Type	Slickwater	
Leak Off Coefficient (ct)	0,014	Ft/min0,5
Flow Behavior Index (n')	1	
Consistency Index (K')	0,0000167	Pa.det0,5
Spurt Loss	0	Gal/100ft2
Viskositas	0,8	Cp

In selecting the fracture geometry, things to consider are the type of formation, the thickness of the prospect zone, the distribution of rock mechanics and the minimum horizontal stress difference. From the data that has been obtained and calculated, the fracture geometry model that is suitable for this layer is Perkirns, Kern, and Nordgen (PKN) because a stress difference of up to 100 psi is found in the upper and lower zones of the prospect zone which indicates the fracture will continue to elongate with fracture height. fixed.

Table 5. Results of the Fracture Geometry of the PKN 2D Model

Nilai		*Satuan*
Height of Fracture	9,81	ft
Long of Fracture (Xf)	481,09	ft
Max. Width of Fracture	0,0236	Inch
Avg. Width of Fracture	0,0148	Inch

From the results of the Stimgun Stimulation Evaluation in the YP-211 well, it was found that the permeability increase from the original 2.1 mD, after fracturing according to the planning permeability increased to 14.07 mD.

Fracture permeability can be calculated using **Equation 5**

$$k_{f=}\frac{(k\ x\ h)+Wkf}{h} \qquad (5)$$

Fracture permeability can be calculated using **Equation 6**

$$k_{avg} = \frac{\log\left(\frac{150}{0.57}\right)}{\left[\frac{1}{15,50}\log\left(\frac{137,2}{0.57}\right)\right]+\left[\frac{1}{2,1}\log\left(\frac{150}{137,2}\right)\right]} \qquad (6)$$

Before the Stimgun work, Qmax = 13 bfpd, Pr = 525 psi and Qopt 12.75 bfpd @ 50 psi (Figure 5). Meanwhile, after Stimgun work, Qmax = 155 bfpd, Pr = 230 psi and Qopt = 140 bfpd @ 50 psi. (Figure 6). There is an increase in production which can be seen in the production graph before and after the Stimgun work in Figure 5. and Figure 6. The increase in production rate is very significant, which is around 1098% or almost eleven times higher.

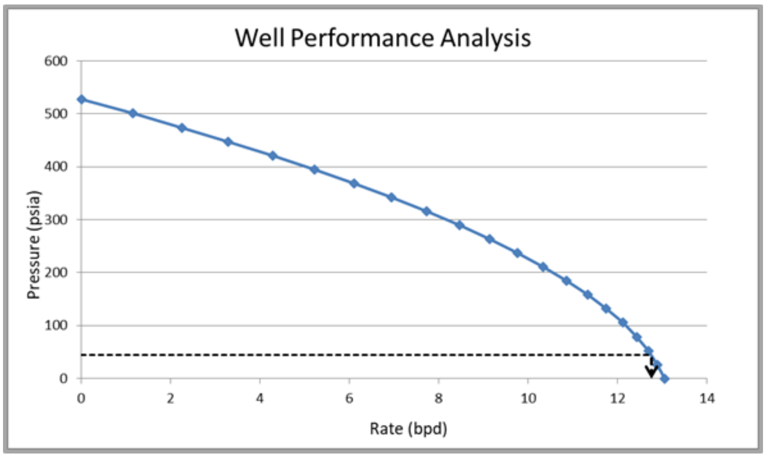

Figure 5. EYP-211 Well IPR Before Stimgun Work

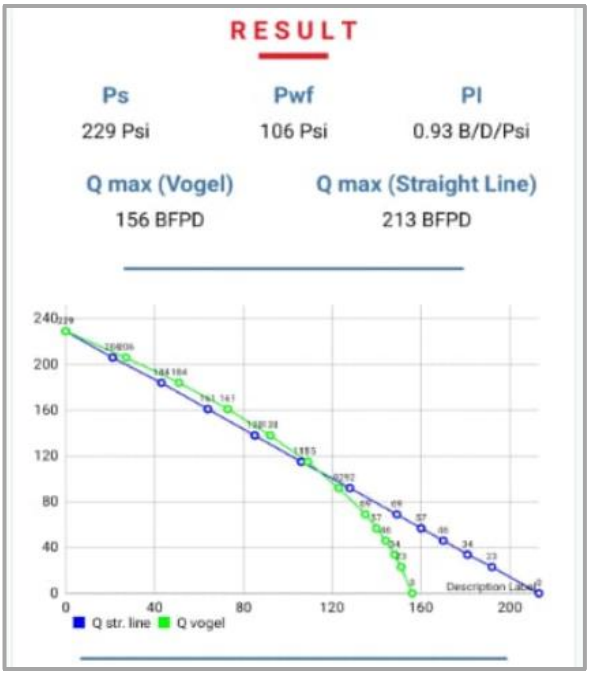

Figure 6. EYP-211 Well IPR After Stimgun Work

3.2. Discussion

Based on the well logging data, the Poisson's ratio value or the comparison between changes in the shape of the lateral strain and axial strain at a depth of 446 m to a depth of 650 m is 0.396. A low Poisson's ratio value indicates that the reservoir rock is suitable for fracturing. The greater the Poisson's ratio, the higher the rock's ability to stretch, in other words, the rock has ductile properties. Rocks that have good prospects for fracture are brittle rocks. The result of a small Poisson's ratio of 0.396 indicates that the reservoir rock is suitable for stimulation.

Young's modulus obtained from the calculation is 7.75 Gpa. A large enough Young's modulus indicates that the rock is stiff enough to withstand stress. The higher the Young's modulus, the more brittle the rock will be. The value of Young's modulus can be used as a reference for determining the stimulation because the fracture produced will be maximized if the stimulation method is carried out on rocks that have brittle mechanical properties.

The reservoir rock in the EYP-211 well has a strike-slip fault with an overburden pressure of 1806.5 psi and a pore pressure of 1151.7 psi. Based on the calculation results, the minimum horizontal stress or minimum pressure so that the rock can fracture is 1534.7 psi and the maximum horizontal stress value based on the calculation results is 1865.5 psi.

The prospect zone is located at a depth of 632.92 m to 635.46 m. The prospect zone is determined from the interpretation of well logging. At this depth the gamma ray reading is low which indicates the rock is clean sand. At this depth, it is also indicated that there is a hydrocarbon content from the high resistivity log reading and there is a crossover in the density log.

A low gamma ray reading indicates that only a few radioactive waves were received, where the emission of these waves is often found in the shale, therefore it can be concluded that there is only a small amount of shale content at that depth. A high resistivity reading indicates the presence of hydrocarbons because hydrocarbons are difficult to conduct electricity.

Determination of the perforation point using a stimgun not only estimates the depth containing hydrocarbons, but also needs to consider the brittleness index and fracable rock in order to obtain the optimum fracture. Based on the rock mechanical properties of Poisson's ratio and Young's modulus in the prospect zone, the brittleness index is 0.54 and the fracability index is 0.56. This value is obtained at a depth of 632.9 m to 635.4 m.

The high value of brittleness index and fracture index of rock will produce more optimum fracture results. Referring to the Altamar & Marfurt constant, the depth point is recommended for fracturing. The brittleness index value exceeds the minimum recommended fracturing limit of 0.48 and the fracability index value of 0.56 is also above the minimum recommended limit for a rock to be fractured, which is 0.55.

In selecting the fracture geometry, things to consider are the type of formation, the thickness of the prospect zone, the distribution of rock mechanics and the minimum horizontal stress difference. From the data that has been obtained and calculated, the fracture geometry model that is suitable for this layer is Perkirns, Kern, and Nordgen (PKN) because a stress difference of up to 100 psi is found in the upper and lower zones of the prospect zone which indicates the fracture will continue to elongate with fracture height. fixed.

Based on the value of Poisson's ratio and Young's modulus, the plane–strain modulus value obtained from the calculation is 1.51x1012 Pa. The maximum fracture width that can be produced is 0.000601503 m or 0.001973531 ft with an average fracture width of 0.000377744 m and a height of 9.81 ft. The length of the fracture produced from the stimgun reaches 147 m. The fracture geometry formed is that the PKN model has the same width along the fracture and is in the shape of a half ellipse at the end. This fracture form has better fracture conductivity. These fractures can be produced with a pressure from the explosive power of the stimgun of 30296.64 psi. Based on the fracture geometry, the fracture volume resulting from the explosion of the stimgun reaches 119.7 gal with a conductivity of 131.5 mD.ft.

The maximum permeability resulting from the stimgun fracture is 15.5 mD and the average formation permeability is 14.07 mD, where there is an increase in formation permeability of 670% which has an initial value of 2.1 mD. Based on the fractures produced by the stimulus, the production flow rate increases as the formation permeability increases.

The production of the EYP-211 well before the Stimgun work was carried out, the maximum flow rate of the EYP-211 well was 13 bfpd and the optimum flow rate was 12.75 bfpd @ 50 psi (Figure 5). Meanwhile, after the Stimgun work, the maximum flow rate was 155 bfpd and the optimum flow rate was 140 bfpd @ 50 psi. (Figure 6). There is an increase in production which can be seen in the production graph before and after the Stimgun work in Figure 5. and Figure 6. The increase in production rate is very significant, which is around 1098% or almost eleven times higher. This proves that the stimgun work on the EYP-211 well is successful and can increase production significantly.

IV. CONCLUSION

4.1. Conclusion

After conducting research in the work of propellant or stimgun stimulation using geomechanical analysis on the EYP-211 well, several conclusions were obtained including:

1. The EYP-211 well is suitable for stimulation based on the brittleness index value greater than the minimum recommended value of 0.55 and the fracability index value greater than the recommended minimum value of 0.56
2. Based on the analysis of interpretation of well logging and rock mechanical properties, the depth of the prospect of the EYP-211 well is 632.92 m to 635.46 m
3. Stimgun work produces fractures with an average fracture width of 0.0149 in, a fracture height of 9.81 ft and a fracture length of 481.19 ft.
4. The average formation fracture after stimulation increased 670% from 2.1 mD to 14.07 mD.
5. Stimgun work on the EYP-211 well succeeded in increasing the optimum production flow rate by 1098% from 12.75 bfpd to 140 bfpd.

ACKNOWLEDGEMENTS

As a writer, I would like to thank Pertamina EP for providing research, knowledge and data.

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