**Analysis Study Of The Effect In Selecting Combination Of Fracturing Fluid Types And Proppant Sizes On Folds Of Increase (FOI) To Improve Well Productivity**

**Dimas Ramadhan 1\*), Hidayat Tulloh2)** **Cahyadi Julianto3)**

1) 2) 3) Petroleum Engineering Department, Faculty Of Mineral Technology, UPN Veteran Yogyakarta

*\** email korespondensi: dimasramadhanftm@gmail.com

**ABSTRACT**

As fracturing materials, fracturing fluid and proppant are two very important parameters in doing hydraulic fracturing design. The combination of fractuirng fluid and proppant selection is the main focus and determinant of success in the hydraulic fracturing process. The high viscosity of the fracturing fluid will make it easier for the proppant to enter to fill the fractured parts, so that the conductivity of the fractured well will be better and can increase the folds of increase (FOI) compared to fracturing fluid with lower viscosity (Economides, 2000). This research was conducted by using the sensitivity test method on the selection of fracturing fluid combinations carried out at the TX-01 well with various sizes of proppants (namely; 12/18, 16/20, and 20/40 mesh) with the proppant selected being ceramic proppant type carbolite performed using the FracCADE simulator. Fracturing fluid was selected based on its viscosity, namely YF240OD and PrimeFRAC20 fluids with viscosity value of 4.123 cp and 171.1 cp, with a fixed pump rate of 14 bpm. The results showed that the combination of high-viscosity fluids (PrimeFRAC20) and 16/20 mesh proppant size resulted in a greater incremental fold (FOI) between the choice of another combination fracturing fluids and proppant sizes, namely 6.25.

**Keywords:** folds of increase; fracturing fluids; hydraulic fracturing; proppant sizes; viscosity.

**I. INTRODUCTION**

Several factors that influence the success of hydraulic fracturing are the design of the fracturing fluid and proppant selection as the fracturing material treatment. Assessment of the success of Hydraulic Fracturing activities can be used the FOI (Fold Of Increase) parameter namely the comparison of the well productivity index after and before hydraulic fracturing. The most important part in fracturing fluid is the viscosity parameter. The importance of viscosity in fracturing fluid is due to its ability to provide high conductivity results and to be able to transport proppants better than low-viscosity fluids, so fracturing fluids with high viscosity will provide a higher folds of increase (FOI) than low-viscosity fracturing fluids.

On the other hand, the development of proppants is also increasingly being carried out, starting with the type of sand, then RCS (resin coated sand) to ceramic proppants whose development is to be able to withstand higher clossure pressure. Furthermore, the selection of the proppant size needs to be done, this cannot be separated from the combination of the fracturing fluid design selection which also affects the amount of the FOI value. The larger the proppant size, the greater the permeability obtained, so that the FOI value will be even greater. In fact, the small size of the proppant is able to enter into between smaller fractures completely so that it can more optimally propped at post-fracturing.

The importance of choosing the fracturing material treatment is the focus in this study, so that it requires a sensitivity analysis on a combination of various types of fracturing fluid and proppant to be sensitive in order to choose which combination has the largest FOI value. Then the results are selected the combination that has the highest FOI value to be used as a reference in designing fracturing materials in the same hydraulic fracturing reservoir planning and / or with different reservoirs but having the same characteristics. So that the results of the sensitivity analysis data from the selection of the fracture and proppant fluid combination become a reference for planning the next hydraulic fracturing stimulation activity.

**II. METHODS**

The design of hydraulic fracturing at the Well TX-01 of "DHC" field was carried out using FracCADE software. The design planning uses the PKN 2D method with the data as shown in Table 1 to Table 6.

**Table 1. Reservoir Data of Well TX-01**

|  |  |  |
| --- | --- | --- |
| **Reservoir Data**  | **Value** | **Unit** |
| Total Depth | 1997.5 | m MD |
| Formation Thickness | 6 | Meter |
| Porosity | 0.28 | Fraction |
| Permeability | 12.4 | mD |
| Reservoir Pressure | 1566 | Psia |
| Fracture Gradient | 0.53 | Psi/ft |
| Pore Gradient | 0.2979 | Psi/ft |
| Temperature | 245 | Deg F |

**Table 2. Rock Mechanics Data of Well TX-01**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Lithology** | **Bottom TVD (m)** | **Bottom MD (m)** | **Modulus Young (psi)** | **Poisson Ratio** |
| Shale | 1603 | 1675 | 5,6456e+05 | 0.2 |
| Sandstone | 1607,8 | 1680 | 5,5643e+05 | 0.2 |
| Shaly | 1610,7 | 1683 | 7,5042e+05 | 0.19 |
| Sandstone | 1611,7 | 1684 | 6,0676e+05 | 0.19 |
| Shale | 1619,3 | 1692 | 6,8275e+05 | 0.2 |

**Table 3. Well Completion Data of Well TX-01**

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Value** | **Unit** |
| Total Depth | 1997.5 | m MD |
| PBTD (Plug Bottom Total Depth) | 1817.5 | m MD |
| KOP (Kick Of Point) | 140 | m |
| Casing Depth |
| Conductor | 82.57 | m MD |
| Surface | 705.6 | m MD |
| Intermadiate | 1545.27 | m MD |
| Production | 1505.88-1972.41 | m MD |
| Completion |
| ID of Poduction Casing | 6.366 | Inch |
| OD of Production Casing | **7** | Inch |
| Tubing 3 ½” | 1667 | mD |
| Interval of Perforation | 1675-1679 | m MD |
| Perforation Number | 50 | - |
| Diameter of Perforation | 0.36 | Inch |
| Radius (rw) | 3.183 | Inch |
| Packer Setting Depth | 1656 | mD |

**Table 4. Hole Geometry Data of Well TX-01**

|  |  |
| --- | --- |
| **Depth** | **Angle** |
| **MD (m)** | **TVD (m)** | **(deg)** |
| 0 | 0 | 0 |
| 82.57 | 82.57 | 0 |
| 140 | 140 | 0 |
| 1603 | 1675 | 30.6 |
| 1679 | 1606.9 | 30.6 |
| 1995.6 | 1880.5 | 30.6 |

The fracture fluid and proppant size selected for analysis of the effect on FOI were YF240OD and PrimeFRAC20 with a viscosity of 4.123 cp and 117.1 cp, while for proppant, a Carbolite type of ceramic proppant was selected with the proppant size sensitivity being 12/18, 16/20 , and the 20/40 mesh shown in Table 4.

**Table 5. Scenario of Fracture Fluid and Proppant Selections**

|  |  |
| --- | --- |
| **Fracture Fluid** | **Proppant Size, Mesh** |
| YF240OD | 12/18 Carbolite |
| 16/20 Carbolite |
| 20/40 Carbolite |
| PrimeFRAC20 | 12/18 Carbolite |
| 16/20 Carbolite |
| 20/40 Carbolite |

**Table 6. Carbolite Proppant Data Properties**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Type** | **Size** | **D (in)** | **ρ (ppg)** | **SG** | **K (mD)** |
| C-Lite | 12/18 | 0.052 | 13.37 | 2.71 | 33810 |
| 16/20 | 0.037 | 13.64 | 2.71 | 126224 |
| 20/40 | 0.028 | 13.64 | 2.71 | 102537 |



**Figure 1. Permeability Graph of Various Size of Carbolite Proppant (FracCADE)**

After obtaining the fracture results from the simulation, such as fracture length (Xf), fracture width (w (o)), fracture height (Hf), and effective conductivity (wkf) from various combinations of fracture fluid selection and proppant size. Next, calculate the FOI value (fold of increase). FOI calculations were performed using the McGuire & Sikora, Cinco-Ley Samaniego and Tinsley & Soliman methods for each simulation treatment carried out with the sensitivity of various combinations of fluid types and proppant sizes.

**III. RESULTS AND DISCUSSION**

Based on the results of calculations and simulations using the PKN 2D method with FracCADE software, the fracture geometry to FOI were obtained from each of the fracturing fluid selection sensitivity and proppant size as follows:

* YF240OD fluid (4.123 cp) combined with 12/18 mesh produces a fracture length (Xf) of 435.5 ft, fracture height (hf) of 15.7 ft, fracture width (w) of 0.5533 inch, and conductivity (wkf) ) of 822 md.ft.
* YF240OD fluid (4.123 cp) combined with 16/20 mesh produces a fracture length (Xf) of 435.5 ft, fracture height (hf) of 15.7 ft, fracture width (w) of 0.5533 inch, and conductivity (wkf) ) of 2957 md.ft.
* YF240OD fluid (4,123 cp) combined with 20/40 mesh produces a fracture length (Xf) of 435.5 ft, fracture height (hf) of 15.7 ft, fracture width (w) of 0.5533 inch, and conductivity (wkf) ) of 2407 md.ft.
* PrimeFRAC20 fluid (117.1 cp) combined with 12/18 mesh produces a fracture length (Xf) of 322.7 ft, fracture height (hf) of 15.7 ft, fracture width (w) of 0.8101 inch, and conductivity (wkf) of 1367.9 md.ft.
* PrimeFRAC20 fluid (117.1 cp) combined with 16/20 mesh produces a fracture length (Xf) of 322.7 ft, fracture height (hf) of 15.7 ft, fracture width (w) of 0.8101 inch, and conductivity (wkf) of 3805 md.ft.
* PrimeFRAC20 fluid (117.1 cp) combined with 20/40 mesh results in fracture length (Xf) of 322.7 ft, fracture height (hf) of 15.7 ft, fracture width (w) of 0.8101 inch, and conductivity (wkf) of 3097 md.ft.

Then the calculation of the comparison of the productivity index after hydraulic fracturing (FOI) using the McGuire & Sikora method, Cinco ley-Samaniego method, and the Tinsley & Soliman method. The results of calculations using the McGuire & Sikora method **(Figure 2)** are 2.06, 3.38, and 3.21 for the viscosity fluid of 4.123 cp with mesh sizes are 12/18, 16/20 and 20/40, the FOI value are 2.49, 4.5 and 3.42 for the viscosity fluid of 117.1 cp with mesh sizes are 12/18, 16/20 and 20/40. The results of calculations using the Cinco ley-Samaniego method **(Figure 3)** are 4.02, 5.77, and 4.86 for the viscosity fluid of 4.123 cp with mesh sizes are 12/18, 16/20 and 20/40, and FOI value of 4.09, 6.25 and 5.18 for the viscosity fluid of 117.1 cp with mesh sizez are 12/18, 16/20 and 20/40. The results of calculations using the Tinsley & Soliman method **(Figure 4)** are 2.27, 3.59, and 2.49 for the viscosity fluid of 4.123 cp mesh sizes are 12/18, 16/20 and 20/40, the FOI value are 2.35, 3.77 and 2.62 for the viscosity fluid of 117.1 cp with mesh sizes are 12/18, 16/20 and 20/40. The results of the calculation of the FOI value are shown in Table 7 below.

**Table 7. Calculation Results of FOI**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Fluid Types** | **Proppant Size, Mesh** | **McGuire & Sikora Method (1960)** | **Metode Cinco ley-Samaniego Method (1981)** | **Metode Tinsley & Soliman Method** |
| YF240OD | 12/18 | 2.06 | 4.02 | 2.27 |
| 16/20 | 3.38 | 5.77 | 3.59 |
| 20/40 | 3.21 | 4.86 | 2.49 |
| PrimeFRAC 20 | 12/18 | 2.49 | 4.09 | 2.35 |
| 16/20 | 4.5 | 6.25 | 3.77 |
| 20/40 | 3.42 | 5.18 | 2.62 |

**Figure 2. FOI Graph of the Mc Guire & Sikora Method on Well TX-01**

**Figure 3. FOI Graph of the Cinco-Ley & Samaniago Method on Well TX-01**

**Figure 4. FOI Graph of the Tinsley & Soliman Method on Well TX-01**

Based on the overall analysis of the calculation results of the FOI, the largest FOI value is 6.25, which is the combination of the choice of fracturing fluid for the type of PrimeFRAC20 with a viscosity of 117 cp with a proppant size of 16/20 mesh. The combination of fluid selection has a fracture length of 416.5 ft with a fracture width of 0.4855 inch and produces a high fracture conductivity of 5167 md.ft. Thus it is recommended that hydraulic fracturing in the TX-01 well be carried out with a high viscosity fracture fluid such as PrimeFRAC20 fluid which has a viscosity of 117.1 cp, then for proppant selection, a proppant with a small mesh size should be selected to form high conductivity so that can increase productivity with optimal hydraulic fracturing design.

The results of the analysis of the effect of selecting the combination of fracturing fluid and proppant size on the amount of FOI indicate that the use of PrimeFRAC20 fluid has a higher viscosity value than YF240OD fluid, this is because the viscosity of PrimeFRAC fluid is higher than YF240OD fluid, so it can provide fracture width and fracture conductivity large because it can transport proppants better than fluids with low viscosity. Likewise with the proppant size, the larger the proppant size (the smaller the proppant mesh value), the greater the conductivity that can be formed after fracturing. In the picture above there is an error for the proppant size 16/18 mesh, this proppant should have a higher conductivity than other proppant sizes, but the conductivity value at 16/18 mesh size in this study is smaller than the others, this is due to its physical properties provided by FracCADE are shown in **Figure** 3.

**IV. CONCLUSION**

Based on the studies that have been carried out in conducting analysis studies on the selection of the combination of fracturing fluid and the sizes of the proppants to the value of folds of increase (FOI) in the TX-01 well of "DHC" field, the following conclusions were obtained:

1. PrimeFRAC20 fluid has a greater FOI value than YF240OD fluid, its because the viscosity of PrimeFRAC fluid is higher than YF240OD fluid, so it can provide greater fracture width and conductivity because it can transport proppants better than fluids with low viscosity.
2. The larger the proppant size (the smaller the proppant mesh value), the greater the conductivity that can form after fracturing.
3. The TX-01 well produced the highest FOI value of 6.25 using a combination of the choice of a fracturing fluid PrimeFRAC20 with a viscosity of 117.1 cp with a proppant size 16/20 mesh C-Lite, so it is recommended for further fracturing in the same reservoir conditions and layers can be to increase the productivity of the well.
4. It is necessary to do further research related to the FOI value for each sensitivity to permeability so that it is expected to increase the productivity of well production.

**REFERENCES**

Allen, Thomas., Roberts, Allan P.,1989, “*Production Operations Volume 2”,* Oil and Gas International Consultants, Oklahoma.

Carl T. Montgomery & Michael Berry Smith, 2015, “*Hydraulic Fracturing*” CRC Press, Boca Raton.

Economides, J. Michael., Hill, Daniel A.,1994, “*Petroleum Production System*”, Prentice Hall PTR, New Jersey.

Economides, J. Michael., Nolte., K.G.,2000, “*Reservoir Stimulation 3rd Edition*”, Schlumberger Educational Services, Houston, Texas.

Economides, J. Michael.,2007, “*Modern Fracturing Enhancing Natural Gas Production*”, BJ Services Company, Houston, Texas.

Feng Liang & Mohammed Sayed, 2015, “*Overview of Existing Proppant Technologies and Challenges*” SPE 172763-MS.

Fred Aminzadeh, 2019, “*Hydraulic Fracturing and Well Stimulation*”, Scrivener Publishing LLC, River Street, Hoboken.

Guo, Buyon dkk,2017, “*Petroleum Production Engineering*”, Professional Publishing, Oxford.

Hoss Belyadi, Ebrahim Fathi, Fathemeh Belyadi, 2017, “*Hydraulic Fracturingin Unconventional Reservoirs: Theories, Operations, and Economic Analysis*” Gulf Professional Publishing, Kidlington, Oxford.

Jack R. Jones and Larry K. Britt.,2009, “*Design and Apraisal of Hydraulic Fracturing*, Society Of Petroleum Engineers, United States

Miskimins Jennifer, 2019, “*Hydraulic Fracturing: Fundamentals and Advancements*, Society of Petroleum Engineers, Texas.

Suwardi,2009, “*Evaluasi Hydraulic Fracturing dalam Rangka Peningkatan Produktivitas Formasi*”, Jurnal Ilmu Kebumian Teknologi Mineral Vol. 22, Universitas Pembangunan Nasional Veteran Yogyakarta.

V. P. P. de Campos, E. C. Sansone, and G. F. B. L. e Silva, 2018, “*Hydraulic Fracturing Proppants*” Cerâmica, 219-229.