INTI JOURNAL | eISSN:2600-7320
Vol.2020:18

A Review of Challenges in Hydraulic Fracturing Operation

Amer S. A. Al Jabri* and Girma T. Chala

International College of Engineering and Management, P.O. Box 2511, C.P.O Seeb 111, Muscat, Oman.

***Email:** a.aljabri-7@hotmail.com

Abstract

Hydraulic fracturing is a prominent method of enhancing hydrocarbon production. It has been implemented from decades to drain the hindered hydrocarbons from the reservoir to the wellbore efficiently. It was reported that a higher percentage of crude oil could be produced from treated wells with hydraulic fracturing technique, with production augmentation sustaining for 40 days in specific well conditions. The two most common types of hydraulic fracturing extensively used are propped hydraulic fracturing and acid hydraulic fracturing. Both methods incorporate similar intention of creating better fracturing conductivity inside reservoir formation for an enhanced well productivity. The treatment fluid contains additives and materials which could be extracted naturally and should meet the best fluid optimization to overcome various challenges. The technique is sophisticated and requires high level of professionalisms and geological awareness to do such successful well production treatment. This paper is, therefore, aimed at reviewing an expandable view on some of challenges associated with hydraulic fracturing operation which hampered successful stimulation operation. It also highlights different techniques that could be used in alleviating the challenges encountered.

Keywords

Hydraulic Fracturing, Challenges, Proppant, Acid, Treatment Fluid, Formation damage.

Introduction

Nowadays petroleum products contribute to a higher percentage of the world energy supplies (Chala et al., 2018). Following the drilling of the well to the depth where hydrocarbon found, well needs to be returned to production to get cash flow from extracted black gold and compensate the drilling cost. Some of the wells deliver hydrocarbons easily and some may not, for which treatment called well simulation is vital (Kurison et al., 2019). The rock formation producing hydrocarbons has in nature bulk of rock with spaces or voids between rock grains (Liu et al., 2020). The voids store some hydrocarbons in the form of liquid/gas phases. In several cases, production of hydrocarbons is hampered by obstacles known as formation damage in petroleum industry. This damage blocks voids that are close to the wellbore section. In this line, hydraulic fracturing stimulation helps to bypass the damaged region and induce new paths to succour the flow of hydrocarbons from rock formation to wellbore to expedite well production (Rigzone, 2020; Nyugen et al., 2020). Figure 1 illustrates the mechanism and reveals from the top damaged formation which needs to be stimulated. From the middle,

International Conference on Innovation and Technopreneurship 2020
Submission: 25 August 2020; Acceptance: 24 September 2020

treatment fluid is injected inside formation and remains there for specific time and then flushed to surface. The bottom part demonstrates stimulated formation and the gushing through pores and voids.

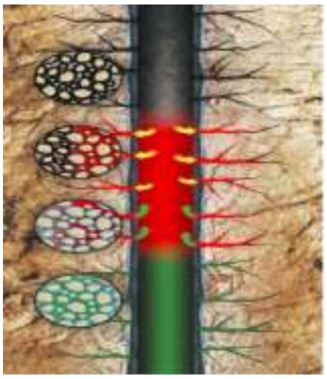


Figure 1: Hydraulic fracturing formation damage removal (Ramakrishna et al. 2016).

Hydraulic fracturing is a technique of injecting fluid mixed with additives called Hydraulic Fracturing Treatment Fluid at both high rate and pressure through well perforation inside reservoir formation to create paths/cracks for hydrocarbons to flow again into wellbore (Huerta et al., 2020; Bai et al., 2020; Chala et al., 2018; Zeng et al., 2020). The paths should have large contact area inside the reservoir formation to be distributed in the formation matrix to drain the remaining hydrocarbons efficiently. After the stoppage of injecting hydraulic fracturing treatment, the initiated cracks tend to close as the injection pressure drops. Leads to lowering the permeability. In this case, a material called proppant is injected with the treatment to hold cracks and remain them open (Daneshy 2010). Hydraulic fracturing technique is widely used in middle east and it is commercially valuable if it is implemented successfully since this can be applied as multistage fracturing for multiple layers (Rahim 2017).

Previous studies indicated that stimulating carbonate formation is simple relatively to sandstone formation since the variation in porosity and permeability of sandstone formation is high (Al-Anzi et al., 2003). Both types of hydraulic fracturing would have similar aim of creating better fracturing conductivity inside the formation for better well productivity (Jeon & Bashir, 2006). For Acid hydraulic fracturing, the acid is mixed with viscous fluid normally to obtain by mixing water with certain amount of polymer and this is injected in formation with a pressure higher than formation fracturing pressure, which lets the fluid leak inside the formation and start etching process. The etched surface should not be smooth and soft so that it remains open after formation is closed due to release of injected pressure (Abass et al., 2006).

For proppant hydraulic fracturing, an amount of proppant is mixed with carrier fluid which is water, polymer and some additives to control the properties of the carrier fluid. The treatment is injected at high pressure to create new path and place the treatment fluid in rock matrix. The treatment fluid would remain inside the formation till it losses its own viscosity, and it would be flushed back to surface while the proppant packed trapped in formation and creates good permeability (Abass et al., 2006). This paper reviews challenges in hydraulic fracturing operation. It provides an expandable view on some of the challenges related with hydraulic fracturing as this hinders successful stimulation operation. In addition, cost of hydraulic fracturing operation is discussed.

Geological Challenges in Hydraulic Fracturing Operation

Geological challenges are considered as the utmost difficult challenges encountering in the design of hydraulic fracturing and execution. It was reported that many of hydraulic fracturing jobs ended up with unsuccessful treatment due to surface equipment, geological characteristics of formation, and well completion limitation. It is sophisticated process requiring high level of professionalism and competence to do better successful fracturing stimulation. Along with that, there are some challenges during treatment that can be faced. Some of them related to rock geomechanics and some of them to fluid treatment design (Alkanaan et al., 2014).

In-situ stress, low permeability, low porosity, extreme formation temperature, high variation in pore pressure, and high fracture gradient are the significant challenges in deep wells (Lamers et al., 2013). High variation in confined rock stress influences the fracturing strategy perforation spots location as well as the completion of the well (Chavez et al., 2013). Formation stresses can be superior at deep wells ranging between 4000 and 5000 m. Developing tight gas reservoir is very critical. Fracturing tight formation involves successful initial propagation that depends more on formation stresses. Core sample is essential to analyse rock geomechanics in order to determine the magnitude of in-situ stresses (Chavez et al., 2013). Hydraulic fracturing can be performed in shall formation to enhance gas recovery from it as in Figure 2. Frac fluid along with proppant sand are injected into formation to create cracks and then trapped gas would be free to release and flow out of formation.

Figure 2: Fracking tight shall formation (Anttu Lein, 2014).

Not only placing the initial propagation in deep wells is difficult, but also the extreme temperature is another challenging factor. Temperature remains as a critical factor in designing hydraulic fracturing fluid. A logging tool with wire operation is used in the well to record formation temperature for the purpose of hydraulic fracturing treatment design. It was observed that this tool has difficulties to read temperature ranging between 160^{o}C and 190^{o}C. Moreover, it was observed failing in some operations (Lamers et al., 2013). Pressure plays a big role in inducing formation fracturing, mainly to overcome the in-situ stress. In some instances, because of the overstressed formation and the limitation of surface equipment especially when pumping high viscous fluid inside formation throw perforation it is challenging to create fracturing. This requires looking for possibility to have lower friction pressure and implement it in fracturing propagation (Janu et al., 2017).

High Pressure High Temperature “HPHT” wells and rock heterogeneities can maximize the hydraulic fracturing treatment challenges (Janu et al., 2017). Drilling horizontal well can aide production and stimulation success. It enhances the drawdown of the reservoir to wellbore. As stated before, the main idea of stimulating the well by hydraulic fracturing is to achieve the Ultimate Recovery by enhancing the hydrocarbons formation deliverability. With both horizontal type of drilling and hydraulic fracturing can get the ultimate production (Janu et al., 2017). On the other hand, stimulating horizontal wells is much complex when compared to the vertical one. This the reason why selecting the best techniques should give the top priority for better well economics and successful operation (Sayapov et al., 2018).

Treatment Design

Hydraulic fracturing treatment design is also one of the challenging factors in this stimulation process. The treatment fluid should meet the best fluid optimization to overcome geological challenges, environmental reduction impact and finally cost effectiveness. The fluid has to be stable during the injection period for successful proppant transportation inside treated pipeline, wellbore and formation, which can be difficult in HPHT wells (Moiseenkov et al. 2013).

Fluid viscosity could also lead to unsuccessful fracturing treatment placement inside formation. Fluid should be able provide sufficient suspension to transport proppant inside opened fracturing. If the viscosity is not optimum, bridging would occur inside wellbore and block the perforations and latter cause screenout (Willingham et al., 1993). Figure 3 shows the arrangement of proppant sand in formation propagation after flushing back treated formation. Proppant is usually designed to be spherical in shape to form spaces between each proppant sand so that hydrocarbons can easy percolates in between.

Figure 3: Proppant used in Hydraulic Fracturing (John et al., 2018)

Well production sustainability

According to EIA (U.S Energy Information Administration), oil production from hydraulically fractured wells now makes up about half of total U.S. crude oil production. Statistics shows that from 2000-2015 the oil extracted from hydraulic fracturing techniques increasing till it reached 51% of the crude oil produced from treated wells with Hydraulic fracturing technique compared to 49% not hydraulically treated from the total number of united states producing wells in 2015. Figure 4 shows that the fracturing technique is well understood and well implemented and about 51% of country oil production was achieved by this technique (Jack Perrin and Troy Cook, 2016).

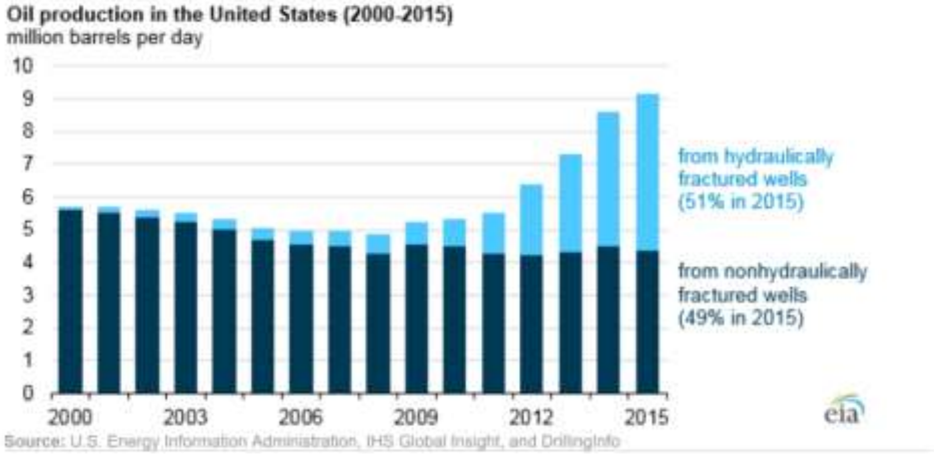


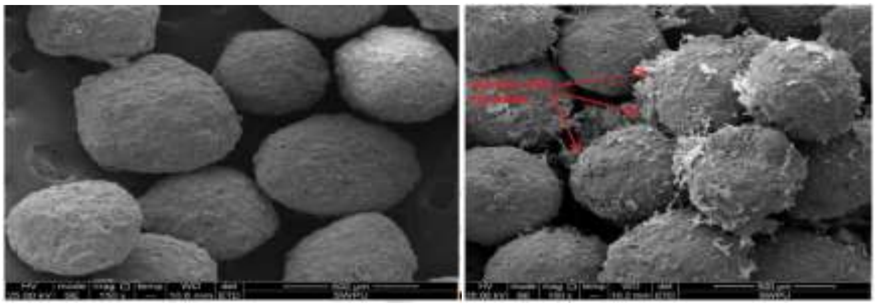
Figure 4: U.S. Crude production compression between hydraulically fractured wells and non-hydraulically fractured wells (Jack and Troy 2016)

One of the challenges encountered in hydraulic fracturing operation is the sustainability of well production after stimulation treatment. The technique provides production sustainability for long period of time unless some parameters alter the conductivity of rock formation again. The formation conductivity can be affected by the proppant pack and residues remaining of broken gel in rock formation. As a general operational procedure, the injected hydraulic fracturing treatment needs to be cleaned from formation matrix likewise the proppant retained from formation should be less and the proppant should be able to hold formation closure pressure to remain spherical inside treated formation. It was also reported that 25% of porosity of proppant -pack could sustain up to 40 days in well temperature of 150^{o}C with closure stress of 41 MPa (Weaver et al., 2006).

Formation Damage

Optimizing fracture treatment fluid is crucial and it has been looked for by the majority of oilfield companies. This approach has big influence in reducing formation damage as well as treatment cost. The main target of well stimulation is to enhance the permeability of rock formation. However, in real field, the treatment fluid used to increase the productivity of the well has an impact on formation damage as well. The fracturing fluid is designed to loss its ability to care proppant sand after placing it in fractured formation. This is accomplished with the help of an additive known in the industry by Breaker and it is ammonium persulfate material. Breaker is pumped along with fracture fluid slurry to break the fluid after certain time from stimulation job completion. When gel breaks, an amount of polymer would residual as small particles in the proppant pack. This residual remains and clogs the proppant pack after flushing the broken gel out from the matrix.

This permeability damage was examined in advanced laboratory machine to understand how the polymer can alter the permeability in order to minimize this impact and maximize the benefits of production gain after stimulating well formation. Figure 5 shows SEM image from advanced hydraulic fracturing laboratory that have been taken to study intimately the impact of broken gel. Figure 5a was taken for clean proppant pack prior placing gel while Figure 5b depicts after the gel was placed and broken and there are some clogs between proppant particles.



(a) (b)

Figure 5: SEM image: a) of Clean proppant pack, and b) for broken gel residual altering proppant pack permeability (Liu S. et al.,2020)

There are some clogs of broken gel residual between proppant particles which certainly altering proppant pack permeability. There are different types of polymer which they differ in terms of the percentage of residual generate in formation matrix. Figure 6 shows another experiment captured to evaluate the broken gel residual in proppant pack for the purpose of reducing formation permeability damage.

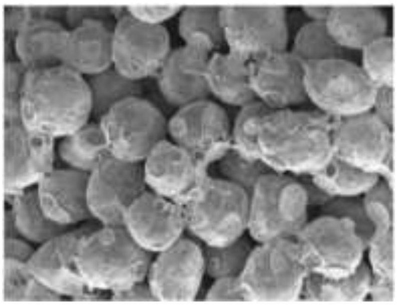


Figure 6: Broken gel residual in proppant pack (Halliburton Company, 2004)

Pumping high concentrated polymer-based fluid increase the polymer residue between proppant back. Figure 7 illustrates this phenomenon. It is for HPG Polymer type at different concentration rate. The percentage of permeability damage rate increases with an increase in HPG Concentration after brine flushing.

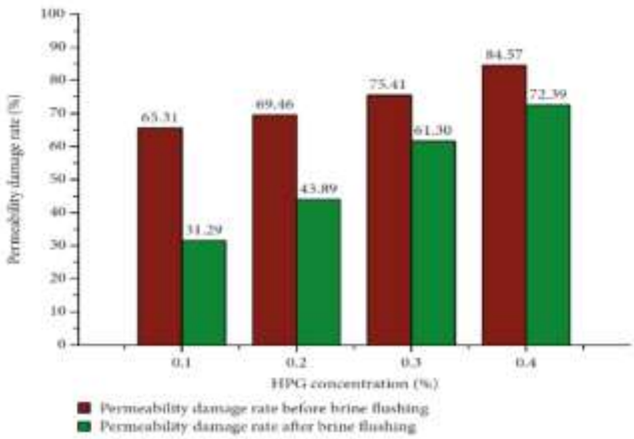


Figure 7: Permeability damage rate vs HPG Concentration pumped (Liu et al., 2020)

Pumping less concentration as possible will help to lower permeability damage. Low concentration of additives good fluid performance are what oilfield companies looking for. With less formation damage, the productivity of the well will be maximized, and this increases the profit and makes the stimulation process financially successful. The rate of damage varies and depending on the type of additives used. Some are low formation damage, and some are high.

Cost of Hydraulic Fracturing Operation

Though this type of stimulation provides huge production gains, the cost of this technique is relatively high, making up approximately about 14- 41% of the total well's cost (JWN staff, 2016). The difficulties in pumping fracturing fluid caused by geological challenges such as in-situ stress of formation could raise the consumption of frac pump horsepower. As a result, the cost would be higher. Besides, chemical usage, number of stages, and fluid volume would impact the total cost. Consequently, there is a need to maximise the benefits obtained from hydraulic fracturing by performing better stimulation execution. Additives usage along with proppant material makes huge portion of overall stimulation cost. Figure 8 illustrates general breakdown of stimulation cost. Proppant is the ultimate expensive material used in Prop Hydraulic Fracturing.

Figure 8: Stimulation Cost Breakdown (Cheung et al., 2018)

Most of Prop hydraulic fracturing is expensive due to the significant cost of the material pumped to accomplish the main aim of the technique. This is one of the reasons in regard to challenges in hydraulic fracturing cost (Cheung et. al., 2018). Stimulating challenging formation may also require additional rock evaluation to design the best treatment solution for the candidate formation such as core sampling and laboratory investigation. This type of evaluation is expensive to be conducted. Special equipment and additional additives are required to stimulate complicated geology or sensitive formation to aid the stimulation operation success or to avoid any formation damage and lost production after stimulation. Additional cost is added to accomplish this prevention (Huff et al., 2013).

Conclusions

This paper reviews challenges encountered during hydraulic fracturing operations. Hydraulic fracturing operation is a sophisticated process requiring high level of professionalism and competence to do successful fracturing operation. Geological challenges are the most difficult challenges that encounter in this type of operation such as In-situ stress, low permeability, low porosity, high variation in pore pressure, high fracture gradient, extreme formation temperature. Overstressed formation requires high pressure to place initial formation propagation. A combination of HPHT well characteristic and rock heterogeneities exploits the hydraulic fracturing treatment challenges. Intensive evaluation is advised to be conducted to each stimulation attempt in the field to have superior understanding about nature of geology and associated challenges for successful Hydraulic Fracturing operation. Use of logging tool interpretation will expedite formation challenges identification. Treatment design is not an easy task in hydraulic fracturing operation when complicated geology existed, and it should accomplish best fluid treatment optimization as well to acquire perfect well production sustainability. Hydraulic fracturing operation aims to reduce formation damage that could be resulted from utilizing some additives or material in treatment blend to protect the productive formation and intensify the benefits of this type of technology. Minimizing treatment chemicals consumption ultimately provides two benefits: reducing formation damage and cost of the treatment. More attention is required in selecting and evaluating proppant material. All proppant test evaluation should not be ignored since this material has solid impact on the Ultimate Production Recovery and it is expensive material. The overall cost of the treatment should be evaluated prior to conducting the technique since this type of stimulation is quite expensive and production gain after stimulation would not compensate the treatment cost in certain cases.

References

Abass, H. H., Al-Mulhem, A. A., Alqam, M. H., & Khan, M. R. (2006, January). Acid fracturing or proppant fracturing in carbonate formation? A rock mechanics view. In SPE Annual Technical Conference and Exhibition. Society of Petroleum Engineers.

Al-Anzi, E., Al-Mutawa, M., Al-Habib, N., Al-Mumen, A., Nasr-El-Din, H., Alvarado, O., & Lungwitz, B. (2003). Positive reactions in carbonate reservoir stimulation. Oilfield Review, 15(4), 28-45.

Aliu, A. O., Guo, J., & Wang, S. (2017). Quantifying regain conductivity in proppant packs using broken Na-CMC fracture fluid. Journal of Natural Gas Science and Engineering, 46, 108-118.

Al-Kanaan, A. A. (2014, January). Hydraulic Fracturing Best Practices. In 21st World Petroleum Congress. World Petroleum Congress.

Anttu Lein, 2014. Shale Energy: How Does Hydraulic Fracking Work?.TECHHYDRA. Available at: http://techhydra.com/tech-news/energy/shale-energy-hydraulic-fracking-work/. (Accessed on 26 April 2020).

Bai, Q., Liu, Z., Zhang, C., & Wang, F. (2020). Geometry nature of hydraulic fracture propagation from oriented perforations and implications for directional hydraulic fracturing. Computers and Geotechnics, 125, 103682.

Chala, G. T., Sulaiman, S. A., & Japper-Jaafar, A. (2018). Flow start-up and transportation of waxy crude oil in pipelines-A review. Journal of Non-Newtonian Fluid Mechanics, 251, 69-87.

Chala, G. T., Abd Aziz, A. R., & Hagos, F. Y. (2018). Natural gas engine technologies: challenges and energy sustainability issue. Energies, 11(11), 2934.

Chavez, J., Mjeni, R., & Briner, A. P. (2013, January). Formation Breakdown Prediction for the Implementation of Hydraulic Fracturing on a HPHT Tight Gas Reservoir in Oman. In SPE Unconventional Gas Conference and Exhibition. Society of Petroleum Engineers.

Cheung, B., Hilling, S., & Brierley, S. P. (2018, November). Impact of Low-Cost Proppant and Fluid Systems in Hydraulic Fracturing of Unconventional Wells. In Abu Dhabi International Petroleum Exhibition & Conference. Society of Petroleum Engineers.

Daneshy, A. (2010). Hydraulic fracturing to improve production. The way ahead, 6(03), 14-17.

Huerta, N. J., Cantrell, K. J., White, S. K., & Brown, C. F. (2020). Hydraulic fracturing to enhance injectivity and storage capacity of CO2 storage reservoirs: Benefits and risks. International Journal of Greenhouse Gas Control, 100, 103105.

Huff, T., Cook, S., Trebing, R., Glover, M., Garza, T., & Thieu, V. (2013, September). Simple and Cost-Effective Hydrate Prevention for Flowback After Hydraulic Fracturing: Kinetic Hydrate Inhibitor (KHI)/Methanol Mixture. In SPE Annual Technical Conference and Exhibition. Society of Petroleum Engineers.

Jack Perrin and Troy Cook, 2016. U.S. Energy Information administration. Available at: https://www.eia.gov/todayinenergy/detail.php?id=26112. Accessed on 27 April 2020.

Juan, C., Mohamed, H., Fahad, A., & Ali, A. G. (2017, November). Horizontal Wells Hydraulic Fracturing from Tight HPHT to Multilayer Differential Depleted Gas Accumulations in Oman. In Abu Dhabi International Petroleum Exhibition & Conference. Society of Petroleum Engineers.

Jeon, J., Bashir, M. O., Liu, J., & Wu, X. (2016, August). Fracturing carbonate reservoirs: Acidising fracturing or fracturing with proppants? In SPE Asia Pacific Hydraulic Fracturing Conference. Society of Petroleum Engineers.

John M. et. All, 2018, improving well economics with advanced proppants. Available at: https://www.hartenergy.com/exclusives/improving-well-economics-advanced-proppants-176870. Accessed on 28 July 2020.

JWN staff, 2016. Here are the five biggest costs for a frac job. Jwnenergy. Available at: https://www.jwnenergy.com/article/2016/7/here-are-five-main-costs-frac-job-us/. Accessed on 29 April 2020.

Kurison, C., Kuleli, H. S., Mubarak, A. H., Al-Sultan, A., & Shehri, S. J. (2019). Reducing uncertainty in unconventional reservoir hydraulic fracture modeling: A case study in Saudi Arabia. Journal of Natural Gas Science and Engineering, 71, 102948.

Lamers, E., Al Siyabi, H., Briner, A. P., Elliott, D. A., Weissenback, M., & Al-Kindy, F. (2013, January). Tight Gas Development in North Oman. In SPE Unconventional Gas Conference and Exhibition. Society of Petroleum Engineers.

Lindsay Lazarski. The Pennsylvania Guide to Hydraulic Fracturing, or 'Fracking'. Stateimp actPennsylvainia. Available at: https://stateimpact.npr.org/pennsylvania/tag/fracking/. Accessed on 27 April 2020.

Liu, S., Huang, J., Tang, S., Shi, S., Wu, X., & Liu, X. (2020). Experimental Study on the Damage of Artificial Fracture Permeability in Coal during the Flow Back of Guar-Based Fracturing Fluid. Geofluids, 2020.

Liu, R., Liu, J., Wang, J., Liu, Z., & Guo, R. (2020). A time-lapse CSEM monitoring study for hydraulic fracturing in shale gas reservoir. Marine and Petroleum Geology, 104545.

Moiseenkov, Alexey, et al. 2013. Six Steps to successfully Design and Execute Hydraulic Fracturing in the Khulud Exploration Area, North Oman. SPE Unconventional Gas Conference and Exhibition. Society of Petroleum Engineers.

Nguyen, H. T., Lee, J. H., & Elraies, K. A. (2020). A review of PKN-type modeling of hydraulic fractures. Journal of Petroleum Science and Engineering, 107607.

Rahim, Z., 2017. Technology Focus: Hydraulic Fracturing. Journal of Petroleum Technology, 69(03), pp.45-45.

Ramakrishna Ponnapati et al., 2016.Optimizing Production, Economics in Mature Fields, HARTENERGY. Available at: https://www.hartenergy.com/exclusives/optimizing-production-economics-mature-fields-176229. Accessed on 27 April 2020.

Rigzone. How Does Well Fracturing Work to Stimulate Production?.Available at : https://www.rigzone.com/training/insight.asp?insight_id=319. (Accessed on 26 April 2020).

Sayapov, E., Al Farei, I., Al Salmi, M., Nunez, A., Al Shanfari, A., Al Gheilani, H., ... & Yakovlev, T. (2018, November). Hydraulic Fracturing in Horizontal Depleted Gas Wells-Challenges, Solutions, Lessons Learnt. In Abu Dhabi International Petroleum Exhibition & Conference. Society of Petroleum Engineers.

SlidPlayer, Salah Eddine Ben Abdallah. Confidential –Internal Halliburton Use Only. © 2004 Halliburton. All Rights Reserved." Stimulation Techniques Fracturing Fluids Proppants. Available at: https://slideplayer.fr/slide/14180850/. (Accessed on 15 May 2020).

Weaver, J. D., Nguyen, P. D., Parker, M. A., & van Batenburg, D. W. (2005, January). Sustaining fracture conductivity. In SPE European Formation Damage Conference. Society of Petroleum Engineers.

Willingham, J. D., Tan, H. C., & Norman, L. R. (1993, January). Perforation friction pressure of fracturing fluid slurries. In Low Permeability Reservoirs Symposium. Society of Petroleum Engineers.

Zeng, Z., & Harouaka, A. (2020). A new method for assessing stage-based hydraulic fracturing quality in Wolfcamp formation of Permian Basin. Journal of Petroleum Science and Engineering, 107740.