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Hydraulic Fracturing Process Systems and Fluids: An Overview

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Mini Review

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Abstract

Hydraulic fracturing has become a critical component of global petroleum and natural gas development, with most the countries around the globe, for example, Canada, India, England, and China actively pursuing the implementation of this technology to increase oil production after declination as well as tap into this new source of energy. Hydraulic fracturing has created jobs and increased revenue in several states across the country. However, as with any advanced technology, there are concerns about its long-term environmental impact. Thus, many researchers and technicians continuously conduct advanced studies to inform industries about any new or upcoming regulations. In this study, a mini-review of the fracking process is considered an important section of the petroleum and natural gas industries. Moreover, researchers demonstrated knowledge about the frac systems and different hydraulic fracturing fluids that are utilized for a fracking job which were different from one fracking system to another in addition to the nature of the reservoir formation. It is a significant factor that production engineers take into consideration when applying hydraulic fracturing to enhance oil or gas production and treat the formation damage, as well. Since the formation damage considers the most critical issue affecting oil and gas production due to fine migration.

Keywords: Fracking; Hydraulic fracturing; Frac fluid; Hydrocarbon; Oil reservoirs

Introduction

Fracking is a common method for increasing hydrocarbon production that involves laying down a network of highly conductive fractures around a wellbore [1-4]. Figure 1 illustrates the fracking job in which 3-5 million gallons of injected water in addition to proppant and chemical additives by applying thigh-pressure process in the presence of several huge tracks to frac the reservoir and connect between formation pores to enhance the permeability again [5,6].

Fracturing has the interest of many researchers. Bin Chen, et al. [7], conducted compressive state of art on hydraulic fracturing simulation and numerical modes are discussed. Nevertheless, Barati, et al. [8] reviewed the traditional high viscous frac fluids for conventional fracking operations in addition to the modern group of fluids that have been developed for both kinds of reservoirs (conventional and unconventional).

The fracture network not only serves to improve the reservoir formation conductivity but also creates new prospects, which contribute to the production of hydrocarbon. It can be used in verticals as well as wells. The massive increase in hydrocarbon production efficiency caused by the process's large network of fractures has made it economically viable for the petroleum and gas industry to plug into previously untapped hydrocarbon reserves in previously undeveloped tight unconventional reservoirs.

Modern high-volume fracking is a method used to extract natural gas or hydrocarbon from shale and other tight formations, to put it another way, impermeable formations trap hydrocarbon and gas and complicate the production of fossil fuel [9-13]. Large quantities of water, chemicals, and (proppant) sand are hurled into these formations at pressures high enough to fracture the stone, allowing earlier trapped hydrocarbons to flow to the ground [14-17].

Hydraulic fracturing job consumes huge quantities of water and causes many environmental issues. In addition, numerous issues such as water-based fluid which liquid tend to trap in the formation, decreasing the relative permeability of the oil/gas phase, and clay minerals formations swelling [18]. Recently, Carbon dioxide (CO_2) is regarded as a promising innovative working fluid because it does not pose a risk of formation damage and can stimulate more extensive and complex crack networks. Applying a CO_2 fracking job has many positive benefits such as (a) it has lower breakdown pressure which is beneficial for fractures propagation; (b) compared to CO_2 fracturing, water fracturing produces large tensile fractures, facilitation of proppant transport and placement; (c) Even under high-stress anisotropy conditions, CO_2 fracturing can dramatically increase the complexity of artificial networks of fracture; (d) thickened CO_2 tends to create comparatively simple fracture networks than carbon Dioxide, but still, more complex than fresh water; and (e) an appropriate fracking scheme followed by thickened-CO_2 fracturing) can easily create complex networks of fractures and transport proppant to keep hydraulic fractures open [19,20].

Overall, Water-based fracturing outperforms CO_2 fracturing; however, for naturally fractured reservoirs, CO_2 fracturing can be an effective method for stimulating tight/shale oil/gas reserves and hence enhance oil/gas production [21].

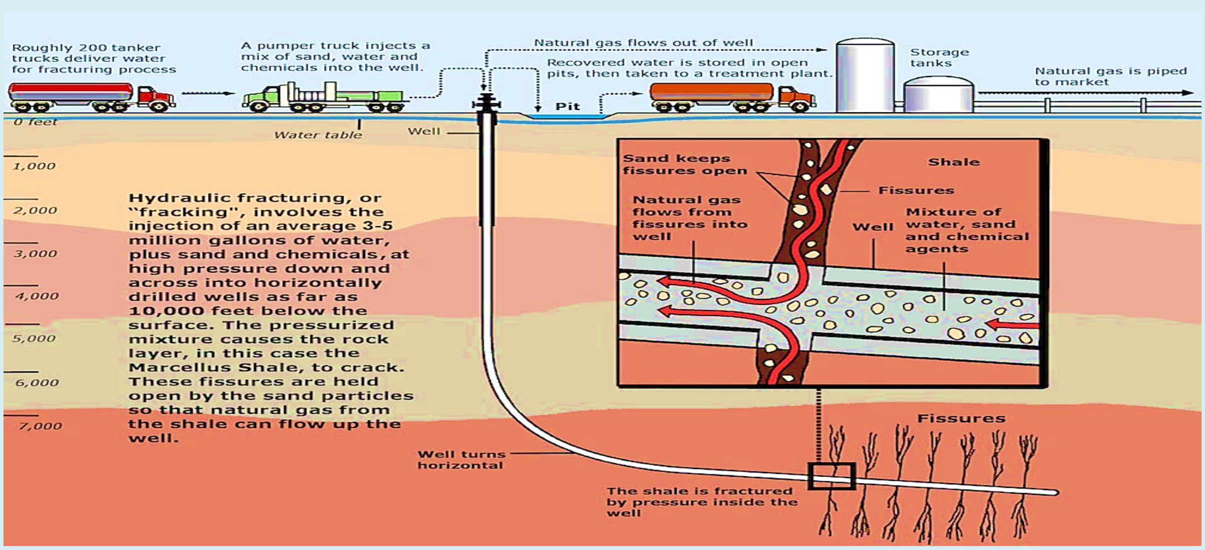

Figure 1: Process of Hydraulic Fracturing [6].

Hydraulic Fracturing Systems

Hydraulic fracking fluid systems have been designed to implement treatment in accordance with the design in order to improve productivity and enhance the Operator's return on the investment. The following critical factors are used to create designs [22-26]: type of the frac Fluid, requirements of viscosity, rheology of frac fluid, the economics of fluid, know-how of formations found locally, laboratory data upon the formation, availability of fracking fluid materials, proppant selection fluid systems optimized to these parameters can result in the minimized formation and fracture face damage for maximized results.

The systems of fracking fluid are contained the following types (friction-reduced water, linear gels, crosslinked gels, or foam) moreover, Table 1 illustrated the various fracking systems including the polymer type utilized for fracking in addition to the crosslinker and maximum applied temperature in Fahrenheit degrees. the fracking fluid methods are listed below:

Water Fracking System: It is mainly composed water, a control agent of clay, and a friction reducer. In some cases, the (WRA) recovery agent of water is added in an attempt to reduce any diffusion coefficient or effects of the water block. The primary benefit of utilizing the Water Frac method is its low cost, ease of mixing, and the possibility of recovering and reusing water. While the disadvantage of this system is its low viscosity, creating a narrow width fracture, as a result [27-29].

Linear Gel Fracking System: It is mainly composed water, a control agent of clay, and the agent of gelling such as Guar, (HPG) hydroxypropyl guar, or (HEC) hydroxyethyl cellulose. These agents are susceptible to bacterial growth and are often used as biostat or bactericides. Chemical breakers were added as well to minimise the damage to the sand (proppant) pack. In addition to being cheaper, a liner gel is also more effective at controlling fluid loss due to its low viscosity. This is because a filter cake is built on the fracture face to prevent the fluid from moving to the formation. The linear gel is the same as the water frac system is low viscous, moreover, the residual water contains a breaker which makes water not reusable [5,27,30].

Crosslinked Gel fracking system: It has the same components as the linear gel in addition to a crosslinker, which increases its viscosity. This type of gel can be used for various applications, such as reducing fluid loss and improving the transport of proppant. Its higher viscosity can also help improve the efficiency of the fluid. This cross-linking improves the elastic properties of the liquid and the mobility of the proppant. The filter cake that accumulates on the fracture surface as the fluid loses fluid to the formation controls the loss of fluid. The accompanying paper for disrupting fluid components contains a detailed description of the cross-linking agents used, as well as the chemistry and mechanism of cross-linking [30-32].

Oil-Based Fluid system: It is used in water-sensitive formations that can be seriously damaged by contact with water-based fluids. The first fracking fluid used to crush the widely used gasoline is a base fluid, palm oil as a gelling agent, and naphthenic acid as a cross-linking agent. napalm. Liquid loss is generally believed to be controlled by viscosity, although some crude oils contain particles that can form filter cakes. C-II. There are some drawbacks to using gel oils. Gelling problems can occur when using high viscosity crudes or crudes containing many naturally occurring surfactants [28,29,33].

Foam/Polyemulsion fracking system: It is fluids composed of water-immiscible materials. This can be nitrogen, carbon dioxide, or hydrocarbons such as propane, diesel, or condensate. These liquids are very clean, have very well controlled liquid loss, provide excellent proppant transport, and break easily by gravity separation. Polyemulsions are formed by emulsifying a hydrocarbon such as a condensate or diesel with water so that the hydrocarbon is the outer phase. Viscosity is controlled by varying the hydrocarbon/water ratio [34-37].

Fluid System	Polymer	Crosslinker	Maximum Temp [F]
CleanStim	Non-Guar	Al	225
PermStim	Non-Guar	Zr, Al	275
EZ-Stim	Guar	B	160
Sirocco	CMHPG	Zr	400
DeepQuest	HPG CMHPG	B, Zr	325
Hybor	Guar, HPG	B	320
SeaQuest	HP	B/Ti	300
Pur-Gel III	CMHPG	Zr	275
pHaserFrac	CMHPG	Zr	275
Delta Frac	Guar, HPG	B	200
Silver Stim LT	Guar	B	100

Table 1: Frac Fluid Systems.

Hydraulic Fracturing Fluids

The hydraulic fracturing process contains water, sand (proppant), and additives that mix together and pump into the well at high pressures to fracture the surrounding formations and create passways and allow hydrocarbon and gas production to increase throughout flowing from created fracture to the production well. The main percentage of the fracking fluid is 99% of water, 0.51% of sand, and 0.49% chemical additives [29,34,38].

The chemical additives utilized in the hydraulic fracking process are involved which are agents of gelling, crosslinkers, reducers of friction, inhibitors of corrosion, scale inhibitors, and biocides are illustrated in Figure 2**.** furthermore, Table 2 shows those types of additives and main chemical compounds applied for a specific role in the fracking process in addition to the purpose of using each additive [35-37,39-43].

Additive Type	Main Compound(s)	Purpose
Diluted Acid (1.5%)	Hydrochloric acid or muriatic acid	Help dissolve minerals and initiate cracks in the rock.
Biocide	Glutaraldehyde	Eliminate bacteria in the water that produces corrosive byproducts.
Breaker	Ammonium persulfate	Allows a delayed breakdown of the gel polymer chains.
Corrosion Inhibitor	N,n-dimethyl formamide	Prevents the corrosion of the pipe.
Crosslinker	Borate salts	Maintains fluid viscosity as temperature increases
Friction Reducer	Polyacrylamide, Mineral Oil	Minimizes friction between the fluid and the pipe.
Gel	Guar gum or hydroxyethyl cellulose	Thickens the water in order to suspend the sand.
Iron Control	Citric acid	Prevents the precipitation of metal oxides.
KCL	Potassium Chloride	Creates a brine carriers fluid.
Oxygen Scavenger	Ammonium Bisulfite	Removes oxygen from the water to protect the pipe from corrosion.
PH Adjusting Agent	Sodium, potassium carbonate	Maintains the effectiveness of other components such as crosslinkers.
Proppant	Silica, quartz sand	Allows the fractures to remain open so the gas can escape.
Scale Inhibitor	Ethylene glycol	Prevents scale deposits in the pipe
Surfactant	Isopropanol	Used to increase the viscosity of the fracture fluid.

Table 2: Fracturing Fluid Additives [35-37,39-43]**.**

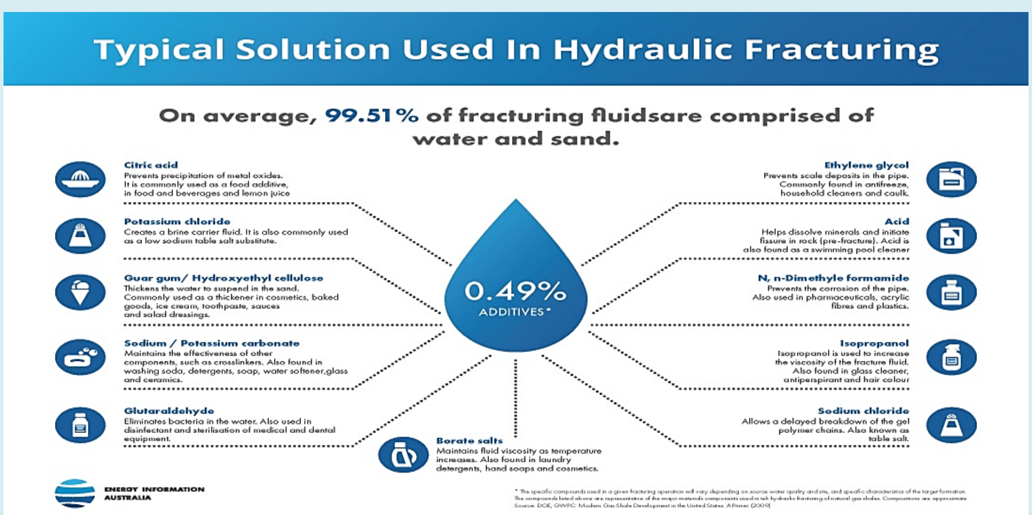

Figure 2: Fracking fluid chemical additives [37].

Conclusion

This is a mini-overview of the hydraulic fracturing process the most important process for induction fracture to enhance the reservoir permeability as well as the production of the well. The frac fluid systems as discussed were water-based, linear and cross-linked gals, oil-based, and foam fluids. Besides, the frac fluid contained water and sand with 99.51% and additives with0.49% which have a vital role in the fracking process. Moreover, for the future prospective of fracking, applying solutions such as the simulation and design of the frac job by mathematical programs and utilizing the AI technology for requirements of fracking optimization and minimizing the cost of fracking. To fill the gap in hydraulic fracturing and reduce the environmental impacts such as air emissions another type which is CO_2 fracturing could be employed.

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