Propellant Stimulation and Hydraulic Fracturing

Essa Georges Lwisa
United Arab Emirates University, Al Ain,
United Arab Emirates,
essa.lwisa@uaeu.ac.ae, essa.lwisa@outlook.com

Abstract

The Propellant Stimulation is applied to increase the permeability of rocks; a certain quantity of explosive material is donated at the bottom of the well opposite the producing layer, which causes many cracks in the near well area. A good Propellant Stimulation process must consider the explosive material quality and quantity, and the explosion should be prevented from vertically spread so all its energy will be used to crack the rocks. The first part of this chapter explains all the above in addition to the directed explosions and its calculation in an easy way.

In the second part, I explained the Hydraulic Fracturing of the reservoir rocks in details, from principal elements of the process passing through cracking fluids, proppants, preparing the wells and ending with evaluating the effectiveness and discussing the methods of hydraulic fracturing. Hydraulic fracturing is the process of pumping fluid into a wellbore at an injection rate that is too high for the formation to accept without breaking. During injection the resistance to flow in the formation increases, the pressure in the wellbore increases to a value called the break-down pressure, that is the sum of the in-situ compressive stress and the strength of the formation. Once the formation "breaks down," a fracture is formed, and the injected fluid flows through it.

Keywords: Hydraulic fracturing, propellant stimulation, enhanced oil recovery, well stimulation, improved oil recovery.

Introduction

Hydraulic fracturing is the process of pumping fluid into a wellbore at an injection rate that is too high for the formation to accept without breaking. During injection the resistance to flow in the formation increases, the pressure in the wellbore increases to a value called the breakdown pressure that is the sum of the in-situ compressive stress and the strength of the formation. Once the formation "breaks down," a fracture is formed, and the injected fluid flows through it. [2]

Propellant Stimulation

The Propellant Stimulation is applied to increase the permeability of rocks; a certain quantity of explosive material is donated at the bottom of the well opposite the producing layer. As a result of the explosion, the explosive materials are suddenly and completely transformed from solid to liquid and then to gaseous, resulting in very high pressure and heat, and the rocks of the stratum are subjected to a violent shock, which is distributed in all directions leading to a partial fracture to the targeted rocks, facilitating the way to the oil towards the well.[1] The resulting waves are distributed in all directions leading to a partial fracture in the near well area, the fractures reach until the distance R (Figure. 1)[2], the area that has the radius R is called "cracked area" and can be extended to 6-8 meters. After this distance, the pressure of the gases decreases significantly due to expansion, therefore, its volume increases, and it penetrates the rock leading to vibration of the rock and may reach up to 10-12 meters. The method is very effective in low-grade producing layers those contain highly saturated with oil but not connected to the well areas. [3]

Explosives

The explosives as solid or liquid substances, alone or mixed with one another, which are in a metastable state and are capable, for this reason, of undergoing a rapid chemical reaction without the participation of external reactants such as atmospheric oxygen. The reaction can be initiated by mechanical means (impact, Impact Sensitivity; friction, Friction Sensitivity), by the action of heat (sparks, open flame, red-hot or white-hot objects), or by detonating shock (Blasting Cap with or without a W Booster charge). Explosive materials are placed in the explosive device, which consists of a cylindrical metallic tube with a shock absorber. The detonator can be ignited electrically by means of the cable that descends the device into the well. [4]

There are many types of explosives used in propellant stimulation, such as Dynamite and Ammonite. [1]

Explosives must meet the following conditions: [5}

1. To release a large amount of energy
2. Not affected by water
3. Have a large capacity, i.e. a small amount of them lead to a severe explosion
4. Have adequate safety
5. Do not pose a risk when transporting or storing
6. Quantity of explosive materials needed

The amount of explosive materials depends on the following factors: [5}

1. Well diameter
2. Dimensions of the targeted area
3. Properties of the explosive materials
4. Properties of rocks exposed to the impact of the explosion, the more hardness of the rocks, the greater the need for energy

To calculate the amount of explosive material, we use the following equation: [3]

$$Vr=0.5 .c.K.g.m.n \quad (1)$$

Where: Vr, volume of cracked area (m3)

c, amount of the explosive material (kg)

K, a constant related to the explosive materials properties, i.e. for dynamite, it is 1.2, and for ammonite, it is 1.0

g, a constant related to the properties of targeted rocks, i.e. for limestone and sandstone is 0.5, and for hard sandstone it is 0.3

m, a constant related to the difference in size between well diameter and blasting device diameter.

n, a constant depends upon the material from which the blasting device is made, i.e. if the blasting device is made from steel, then n= 0.85.

Assuming that the cracked area has a spherical shape where R is its radius, and then its volume could be calculated from this equation:

$Vr=4/3.\pi.R^3=4.18 R^3$ (2)

By combining (Eq. (1)) and (Eq. (2)), the amount of explosive materials could be calculated as follows:

$4.18R^3=0.5 .c.K.g.m.n$ (3)

$c=(8.3R^3)/(K.g.m.n)$ (4)

Preventing vertical spread of the explosion impact

In order to protect the devices mounted on the wellhead and to increase the efficiency of the explosion, its effect must be horizontal only on the walls of the producing layer. One of the procedures to prevent the vertical spread of the explosion is to form pressure on the explosion zone by a column of liquid (Figure. 2). Crude oil is one of the liquids used for this purpose, and its height is calculated inside the well as follows: [3]

$P_o V_o=P_1 V_1$ (5)

$CV_0=\pi/4 D^2 h_e (h_b \gamma)/10$ (6)

Where: C, the amount of explosive material (Kg)

V0, the volume of gases produced by the detonation of 1 Kg of explosive material in the regulatory conditions (m3)

D, well diameter, which equals the inner diameter of production casing pipes (m)

he, the height at which the impact of the explosion can reach with the presence of the liquid column, after neglecting the compression of the liquid (m)

hb, the height of liquid column in the well (m)

γ, specific gravity of the liquid inside the well kgf/dm3

The height of liquid required to prevent the vertical spread of the explosion impact is given by the following equation:

$h_b=40/\pi.(CV_0)/(\gamma D^2 h_e)=12.17 (CV_0)/(\gamma D^2 h_e)$ (7)

For various values of he, we obtain corresponding values for the liquid height. On the contrary, when the effect of the explosion is achieved up to a specified height, the corresponding liquid height is determined, but the sum of the two values should be smaller or equal to the total depth of the well. In some cases, and to prevent the spread of the impact of the explosion towards the axis of the well barriers of plaster, sand, or cement are placed above the area of the explosion. [5]

Directed explosion

This method is applied when we need to focus the explosion effect in a certain direction of the producing layer. It has three types: [5]

1. Concentrated side impact detonation
2. Extended side impact detonation

3. Vertical impact detonation.

All types are shown in (Figure. 3)

Hydraulic fracturing of the reservoir rocks

Hydraulic fracturing is a well stimulation technique in which rock is fractured by a pressurized liquid. The process involves the high-pressure injection of 'fracking fluid' (primarily water, containing sand or other proppants suspended with the aid of thickening agents) into a wellbore to create cracks in the deep-rock formations through which natural gas, petroleum, and brine will flow more freely. [6] When the hydraulic pressure is removed from the well, small grains of hydraulic fracturing proppants (either sand or aluminum oxide) hold the fractures open (Figure. 4). [7]

If the producing layer is made up of tight low-permeability rocks, the effect of hydraulic fracturing is equivalent to an increasing in the diameter of the well, this means that the fluids that were flowing through the tight rocks are now flowing through cracks with large flow potential in the near well area. [3] In the near well area, pressure drops in the fracked area as shown in (Figure. 5).

If the near-well area forms a barrier to flow (preventing flow in completely or partially) as a result of contamination, this method puts the well directly in contact with the non-contaminated area through fractures. [3]

Principal elements of hydraulic fracturing

The process of hydraulic fracturing depends on several factors and is influenced by them. These factors can be divided into two groups: [8]

1. Factors associated with the treatment method, include:
   a. Fracking fluid.
   b. Proppants.
   c. Fracking pressure.
   d. Fracking fluid flow rate
2. Factors associated with the characteristics of the targeted rocks, include:
   a. Permeability
   b. Hardness
   c. Rock consolidation.
   d. The presence of natural cracks
   e. Thickness of the treated area
   f. The specifications of the fracking fluids.

The efficiency of the treatment of the layers in the hydraulic method is highly dependent on the quality and properties of the fluids used, especially viscosity, it also depends on liquid loss.

The viscosity of fracking fluid is designed to do the following: [3]

1. To keep the granules suspended in the fluid it until they reach the newly formed fractures.
2. To achieve the least loss of pressure due to the friction between fluids and the pipes.

In order to transfer the solid granules to the fractures, viscosity should be as high as possible, so solids remain suspended in the fluid but that will increase the pressure lost due to friction, in addition, it is difficult to retrieve viscous liquid from the fractures at the end of the process, but this can be solved by injecting viscosity reducer. To mix and transfer solid granules, two types of liquids are usually used; initially, a low viscosity fluid is used to create fractures, and then a high viscosity fluid is used to transfer the solid granules to the fractures. [9]

The liquid loss plays an important role in the dimensions of the cracks obtained. The smaller the loss, the deeper the fracture is, and the greater the diameter of the cracked area, and vice versa. The effect of liquid loss on the dimensions of the cracks is much greater than the effect of the injection rate of the liquid and its viscosity, as shown in (Figure.6) and (Figure 7).

When the loss of fracturing fluid in the layer is approaching the rate of pumping in the well, the widening of the section decreases, and the continuation of pumping becomes useless, the process of hydraulic fracking in these conditions is similar to the process of flooding of the oil layer with water. [10]

We conclude that fluids with very little or no loss should be used if possible, or that the fluid in the well should be pumped at a significant rate when using high-loss liquids.

Hydraulic fracturing liquids

The fluids used in hydraulic fracturing process varies in terms of chemical composition and physical properties. Since hydraulic fracturing is applied to the production wells and to the injection wells, therefore the selection of fluids must be proportional to the conditions in the layer, especially with regard to the nature of formation fluids. According to this point of view, the fluid used in hydraulic fracturing can be divided into three groups: [10]

Oil based liquids

They contain high-viscosity dead oil, crude oil or one of its derivatives. These liquids must be treated with materials to increase their viscosity and thus increase their ability to carry the proppants. Dead oil is characterized by its great ability to transfer sand grains to the layer, as well as little liquid loss, it is mainly used to frack oil layers. As for the layers containing gas, dead oil is considered inappropriate because it closes the pores and takes a long time to be recovered from the layer, it also has a very bad property that is its viscosity decreases significantly at low temperature. The use of crude oil is suitable for fracking the producing layers except those containing water which may form viscous emulsions with oil. It is preferable to use the newly produced oil from the same layer because it reduces transportation cost and does not pollute the near well area and is easily recovered after the completion of the fracturing process, in order to increase its ability to transport the proppants it may be treated with materials to increase its viscosity and reduce loss due to leakage. It is preferable to use oil-based fluids in the producing layers, which are composed of rocks with a large content of silicates that swell when they are in contact with water. [10]

Water based liquids

These liquids include water and acidic fluids like hydrochloric acid or acetic acid in their normal form or treated to increase their viscosity. When used normally (without treatment), it should be pumped at a high rate so that it can transfer sand grains to the layer and compensate for loss due to leakage. [9] The use of water as fracking liquid has many advantages, including:

1. Ease of access in large quantities and low costs
2. Easy to move and store
3. Its high ability to carry sand grains when treated with viscosity increasing materials.
4. The amount of loss due to leakage is small.

It is recommended to use water-based fluids to frack layers penetrated by the injection wells if those wells are already used to inject water-based solutions. [11]

Emulsified liquids

These liquids combine between the oil-based and water-based liquids by adding emulsification agents, such as Gum Arabic. [11] Emulsions which are formed of acidic liquid as a base and oil as a scatter are most commonly used, where acidic liquid forms 50 to 90 % to their content. Acid concentrations range from 5 to 15% depending on the nature of the layer. The emulsifying material should be chosen so that the emulsion can be easily broken upon completion of the fracking process. Emulsified liquids have a good ability to transfer sand grains to the layer as well as a small amount of loss due to leakage. To prepare emulsified liquids, a variety of materials are usually used, including viscosity increasing materials (e.g. carboxy methyl cellulose), substances to reduce leakage loss, friction reducers (e.g. FR38 TM), anti-swelling materials (e.g. KCl), and emulsifiers. [12]

Proppants

Keeping cracks open after recovering the fracking fluid from the layer is a very important. It is done by injecting solid materials from the surface along with the fracking liquid. The materials used as proppants include the quartz sand grains, which must be of homogeneous and spherical dimensions, aluminum or glass granules or mixtures of quartzite, aluminum and others. The proppants should have the following qualifications: [1]

1. Must be highly resistant to compression.
2. Do not be affected by the fracking liquid or fluids in the layer
3. Must have good permeability when pressed by the frack walls after the pressure reduces due to the recovering of the fracking liquid.
4. To be easy to prepare at low cost.

The diameter of granules depends on the permeability of the layer. If the permeability is less than 100 mD, then dimensions ranges from 0.5 to 0.8 mm. For highly permeable layers, granules dimensions may range from 0.8 to 1.5 mm. In order to ensure large flow potential during the cracks formed, several methods were applied to obtain a homogeneous distribution of solid granules within the fracture. One of these methods is to add some gel-like materials to the fracking liquid, those materials can keep the proppants apart from each other till they enter the fracture, then gels are dissolved and retrieved along with the fracking liquid, which leaves big pores and increases the permeability. [13]

Concentration of proppants in the liquid depends on the fluid's ability to keep them suspended until enter the fracks. This in turn depends on the fluid viscosity, the injection rate and the speed of the mixture. For example, the concentration of sand can reach 450 kg per cubic meter of liquid whose viscosity is 600 cp and injected at 15 liter per second. In some cases, after the completion of the hydraulics process, a significant amount of sand may deposit at bottom of the well due to a high concentration of sands in the liquid or because of the loss of a large amount of liquid in the layers. [13]

When the process is completed, the pressure should be gradually reduced to prevent the sand from being returned to the well.

Preparing the well for hydraulic fracturing

To prepare the wells for hydraulic fracturing, production pipes are lowered in the well, a packer is used to close the annulus between the production and casing pipes, so casing will not be affected by high injection pressure. On the surface, the pipes are equipped with an injection head specially designed to withstand the greatest pressure of injection and equipped with side branches connecting the pumping and piping devices. To reduce the pressure loss due to friction between the pipes and the liquid during the injection, the largest possible diameter of pipes must be used. [13]

Surface units include four groups: [3]

1. Hydraulic fracturing group.
2. Proppants conveying group.
3. Mixing of proppants with hydraulic fracturing group.
4. Pumping group.

Prior to the hydraulic fracturing of the well, a series of preparatory actions should be taken: [3]

1. Measure the rate of well production and pressure at the level of the targeted layer.
2. Inspect the bottom of the well and clean it along with the well walls against the layer when there are sand or granules deposits
3. Check the casing pipes and ensure their validity and the possibility of lowering the injection pipes with the packer to the level of the layer
4. When no information is available about the layer ability to accept the liquid, a small quantity is initially injected to confirm the applicability.

Following these preparations, the process of hydraulic fracturing is carried out according to the following stages: [3]

1. The fracking fluid is injected with the maximum pressure of the injection pumps until the layer cracks.

2. The proppants shall be injected with the sand grains to maintain the opening of the cracks in the maximum pressure as well and without interruption at an average rate equal to the injection fracking fluid at least in order to avoid placing the sand on the bottom of the well, thus re-sealing the cracks after withdrawing liquids from the layer.
3. It is preferable to inject 1.5 m3 of oil after the mixture of liquid and proppants to form a separation between the mixture and viscosity reducer liquid
4. Viscosity reducer solution is injected with the maximum pressure of injection pumps as well.
5. An amount of clean liquid (free of proppants) equals to the volume of the inner size of injection pipes and the volume of the well against the layer is injected to ensure that the entire liquid is entered into the layer.
6. Well is closed under pressure and kept for 24 - 48 hours.
7. The well is re-opened, and the pressure gradually reduced. The well is put in production at a rate that is lower than the pre-fracking rate, in order to avoid carrying the layer fluids of the sand grains from the cracks. This rate is gradually increased to reach the ideal rate of production. [8]

Injecting pressure and treatment pressure

If we analyze the pressure on the entire path through which the fracking liquid passes from the surface until it enters the layer, we can reach the relationship between the injection pressure and the treating pressure. To frack the layer, pressure of the treatment must exceed the critical pressure of the rocks. Injecting pressure is given by the following equation: [3]

$P_p=P_{st}-P_{fl}+P_{fr}$ (8)

e: P_{st}, the treatment pressure which must be equal to or exceed the critical cracking pressure of the rocks, Kgf/cm2

P_{fl}, pressure of the hydraulic fracturing liquid column at the level of the layer, Kgf/cm2

P_{fr}, pressure applied to resist the friction between the fracking liquid and the walls of the injection pipes, Kgf/cm2.

The treatment pressure is given by Crittendon equation:

$P_{st}=KP_s$ (9)

Where: K, Arithmetic constant

P_s, static pressure of the layer, which is given by the following equation:

$P_s=(H\gamma_{rm})/10$ (10)

Where: H, depth of the layer, m.

γ_{rm}, specific weight of the rocks placed above the target layer, Kgf/dm3.

Arithmetic constant, K is given by the following equation:

$K=1/2\ (1+2\mu/(1-\mu)) +(1-2\mu/(1-\mu)\ \cos 2\theta\ )$ (11)

Where: μ, Poisson's ratio

Θ, the angle formed by the fracture and the horizon.

In case of the horizontal fracture:

$\theta=0\rightarrow\cos 2\theta=1\rightarrow K=1\rightarrow P_{st}=P_s$ (12)

In case of the vertical fracture:

$\theta=90\rightarrow\cos(2\theta)=-1\rightarrow K=2\mu/(1-\mu)$ (13)

$P_{st}=2\mu/(1-\mu)\ P_s$ (14)

The pressure of hydraulic fracturing liquid column at the level of the targeted layer is given by the following equation:

$P_{fl}=(H\gamma_{fl})/10$ (15)

Where: γfl, specific gravity of the liquid in the well, Kgf/dm3.

H, height of the liquid from the layer to the surface, m.

The pressure applied to resist the friction between the fracking liquid and the walls of the injection pipes is given as follows:

$P_{fr}=\alpha Q^2 H\gamma_l$ (16)

Where: α, friction ratio.

Q, injection flow, m3/h

H, length of injection pipes, m

γl, specific gravity of the liquid, Kgf/dm3.

From (eq.9), (eq.15), (eq.16) we can write the injection pressure equation as follows:

$P_p=K\ (H\gamma_{rm})/10-(H\gamma_f)/10+\alpha Q^2 H\gamma_f$ (17)

For horizontal fractures:

$P_p=0.1H[(\gamma_{rm}-\gamma_f)+\alpha Q^2 \gamma_f]$ (18)

For vertical fractures:

$P_p=0.1H[(\gamma_{rm}\ 2\mu/(1-\mu)-\gamma_f)+\alpha Q^2 H\gamma_f]$ (19)

The specific gravity of hydraulic fracturing liquid is given by the following equation:

$\gamma_f=(\gamma+\gamma_r n)/(1+n)$ (20)

Where: γ, specific gravity of base liquid

γr,, specific gravity of the proppants.

n, concentration of proppants in fracturing liquid.

Choosing of layers for hydraulic fracturing

Hydraulic fracturing may be applied in the following wells: [9]

1. Wells that penetrate a set of productive layers those have no interference by water or gas. If the layer contains a gas cap and stratified water, the area exposed to the hydraulic fracturing shall be kept away from all gases and water by at least seven meters.
2. Wells where the production pipes are in good condition in terms of construction and are well secured from outside.
3. Newly drilled wells those penetrate low permeability reservoirs and have not been put into production yet.
4. Wells that yield little recovery when put in production compared to adjacent wells or if they cannot be put into production in other ways.

Evaluation of hydraulic fracturing

The increment in the rate of well production after the hydraulic fracturing process can be assessed by the Coefficient of Fracking Efficiency, which represents the production ratio before and after the treatment. Hydraulic fracturing efficiency is given by the following equation: [3]

$$E_f=\frac{(K_{fw}+K_0 h)\ R_c/r_w}{K_{fw}\ \ln(R_c/R_1)+K_0 h \ln(R_c/r_w)} \quad (21)$$

Where: Kfw, permeability of the fracture, mD

K0, permeability of the layer. mD

h, the layer thickness, m

Rc, radius of the well effect area, m

rw, well radius, m

R1, radius of the treated zone, m

When fractures width is between 0.1 and 0.2 mm, the fracturing efficiency is not remarkable; for the best results, the width must be ranging in 1- 2 mm, as shown in (Figure.8) [3]

The efficiency of hydraulic fracturing increases dramatically if the radius of the cracked area is limited to 25- 30 meters, the larger increase in this value will result only in a lower increase in the production rate. If we follow the variable $E_f=f(R_1)$, we note that the efficiency of hydraulic fracturing increases if the initial permeability is lower, as shown in (Figure.9). [3]

Hydraulic fracturing methods

Although the method of hydraulic fracturing is a relatively recent, it has developed rapidly as several methods have been established to be applied to suit the conditions of each well.

Injecting fracturing fluid through casing pipes

At the beginning of this method, the liquid was injected through the production pipes, or through special pipes called injection pipes, which are equipped with a packer at the lower end.

This method is still used so far when the production pipes are weak and cannot withstand injection pressure. If we take into consideration that in most hydraulic fracturing a large quantity of liquid is injected at large rates, the use of production pipes or injection pipes leads to large loss of pressure inside them, and the use of low injection rate leads to sand deposition in the well forming a sand plug, Injection fluid, as well as the fluid that transfers proppants to the layer through the casing pipes with a diameter greater than the diameter of the production pipes, enables the use of high injection rates and leads to low pressure loss due to friction. The pumping rate in this case can reach 10500 liters per minute.

A second method is to inject through production pipes and the annulus at the same time, eliminating the need to lift and lower the pipes before and after the fracking process. Casing pipes must be highly resistant to external pressure, tensile strength and internal pressure. [9]

Fracking through perforation holes

Most hydraulic fracturing processes are carried out through the channels produced by the perforation of the production pipes (Figure.10). This method is different from that of the uncased wells. Its efficiency depends on the ability of the fluid carrying proppants to flow through the holes. The fracturing process is done through the holes as follows: When the fluid is injected with a certain flow rate, the pressure on holes increased up until the moment the layer cracks and forms a fracture or several fractures in front of the holes. If the entire fluid enters the cracks, the pressure is fixed on a certain value, which is the value at which the layer is cracked. [9]

Separated fracturing

Most of the wells that penetrate the produced layers are drilled in areas up to tens of meters in which hydrocarbon-free interferences may occur. When these fields are treated with hydraulic fracture, there is a high probability of fracturing hydrocarbon-free parts or of cracks at levels separating an oil zone from a dry zone, leading to a significant reduction in the effectiveness of the assignment. In order to avoid this, the hydraulic method is applied to the productive layer, where the regions are separated from one another by a packer as follows: [9]

1. If the oil targeted layer is located below the perforated area, then packer is fixed to the top of this layer, allowing the fracking fluid to affect it only, as shown in (Figure. 11A)
2. If the targeted area is in the middle of the perforated area, it can be isolated by two packers. In this case, the production pipe placed between the two packers should be perforated so the fracking fluid passes through the pipes to the annulus between the two packers and reaches the target region.
3. In the case of two product layers separated by an impermeable layer, the packer is stabilized against this layer as (Figure.11B), the bottom layer is then fractured through the production pipes and then the upper layer by injecting the fracking fluid through the annulus between the production and casing pipes, the two layers may be treated simultaneously.

After the treatment is finished, the bottom layer is put in the production through the production pipes, and then the packer is raised to the surface and the top layer is put in the production as well.

When the hydraulic fracturing and proppants injected through the annulus, there is a great possibility for sand deposition on the packer, then to raise the packer sand should be cleaned first, which increases the time taken by the process of fracking as well as the difficulty of cleaning the sand. For this purpose, the production pipes are equipped with a special perforated needle placed above the packer and sealed by a piece fixed with a safety needle. After finishing the fracking, a metal disc is thrown into the production pipes, it lands on the safety needle, as pressure inside the pipes increases, the desk pushes against the needle and eventually breaks it, pipes then are open, and fluid passes into the annulus and clean up the sand positioned early (Figure.11C).

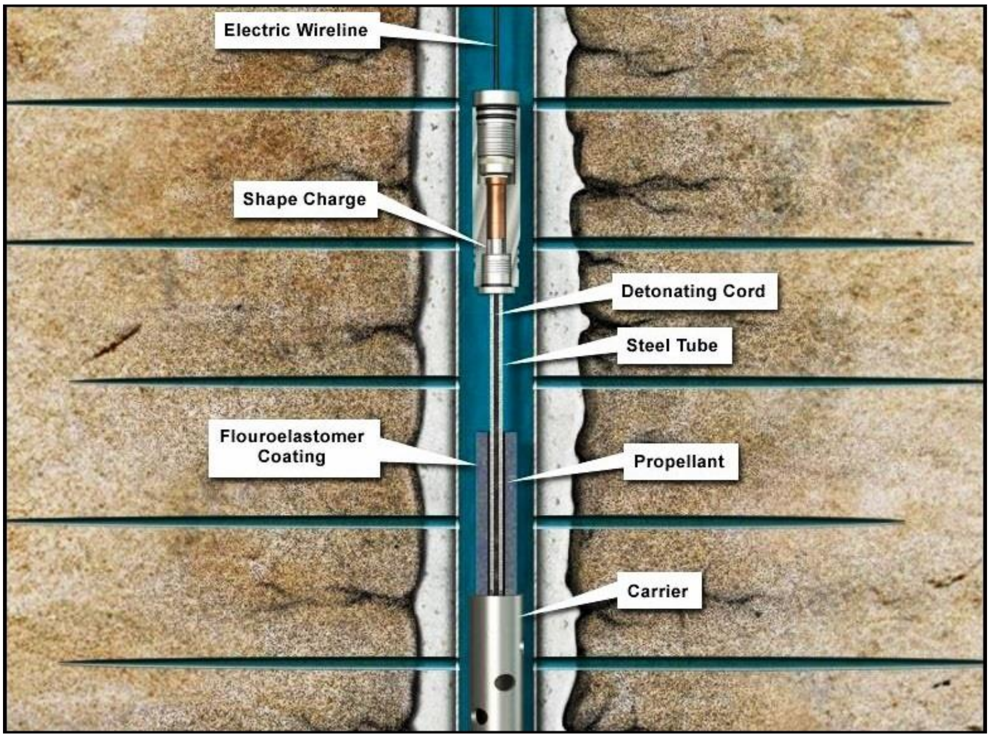
Fracturing by stages

This process enables us to form several cracks at different levels of the produced layer either according to the sequence of rocks consolidation or in any other sequences. It consists of several simple hydraulic fracturing processes using different pressures each time, the cracks formed in the previous stage must be isolated before moving to a new fracturing process. The process is performed as per the following slandered steps: [3]

1. The production pipes fitted with a packer are lowered in the well
2. The packer is fixed at the lower part of the targeted layer.
3. Fracking liquid is then injected till the layer is fracked, a mixture of fracking liquid and sand is pumped through the production pipes.
4. The fracking fluid shall be injected with insulating materials to close the fracks and prevent the entry of liquids into them. Insulating materials used for the temporary insulation of cracks could be rubber or plastic balls. The diameter of these balls should be greater than the diameter of the cracks.
5. After insulating the cracks of the first stage, a second fracking operation is performed with a higher pressure than the first stage hence the harder rocks are fractured. The cracks of this stage are also filled with sand and then insulated.
6. The fracturing process continues in other stages until we reach the maximum pressure.

Hydraulic fracturing by acids as fracking liquids

It is a combination of hydraulic fracturing and matrix acidizing methods which gives better efficiency and greater effectiveness than each method. The acidic liquid that enters the cracks also interacts with the rock, helps widens the cracks and provides effective contact between the layer and the well. [8]



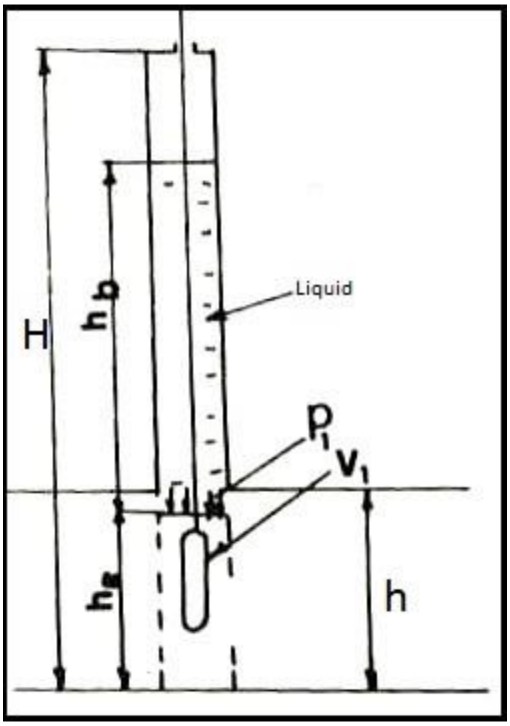


Figure 2: Preventing vertical spread of the explosion impact

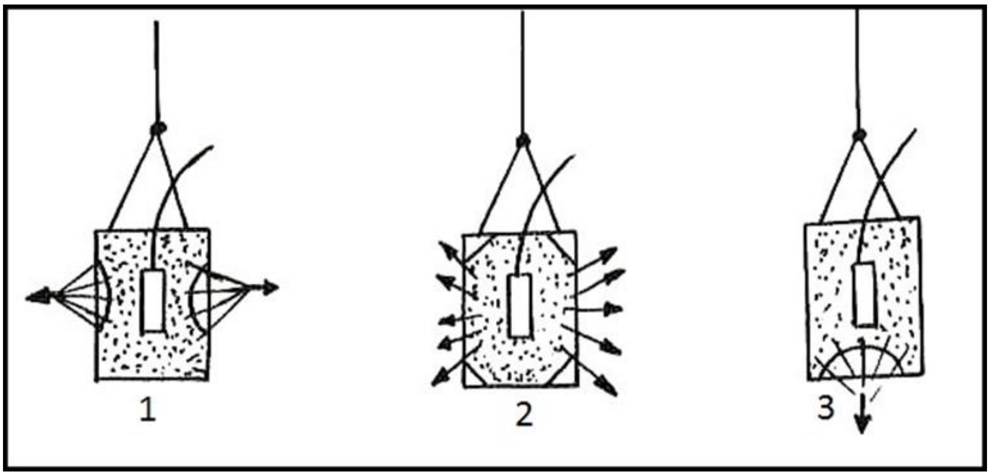


Figure 3: Directed explosion

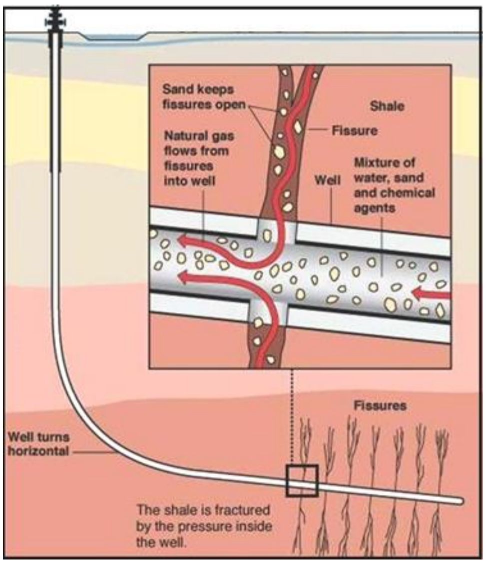


Figure 4: Hydraulic fracturing

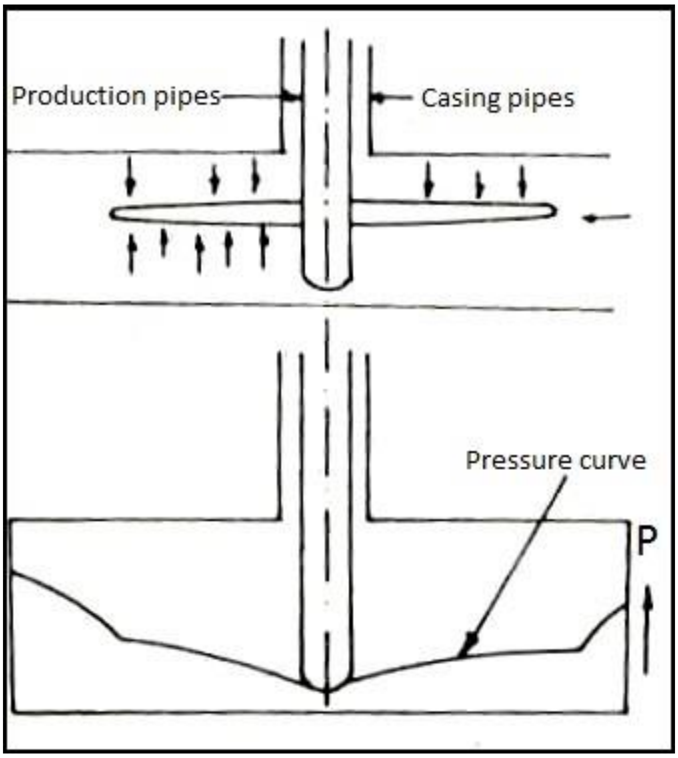


Figure 5: Flow system and pressure curve in the near well area

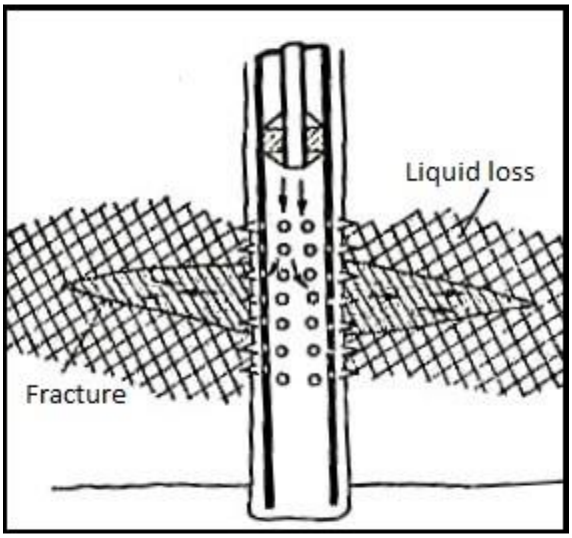


Figure 6: Effect of high liquid loss on hydraulic fracturing

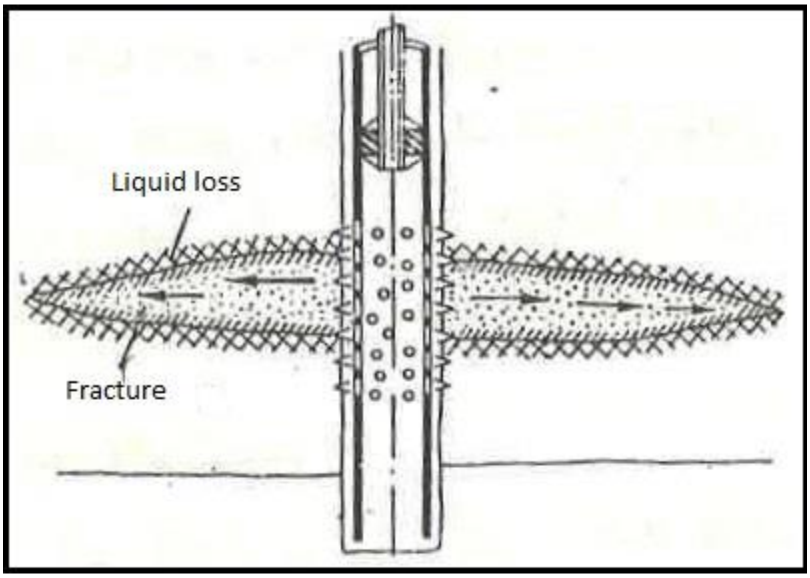


Figure 7: Effect of low liquid loss on hydraulic fracturing

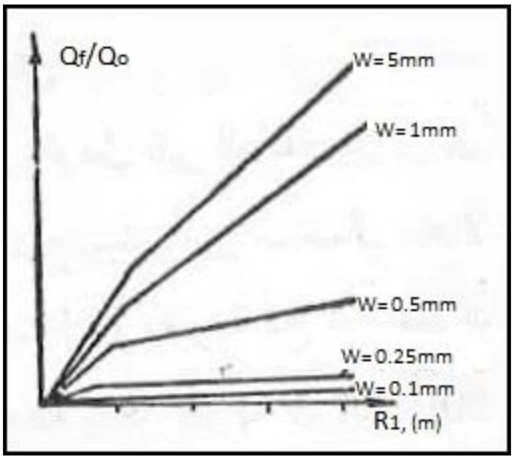


Figure 8: Fracking efficiency VS fracture width

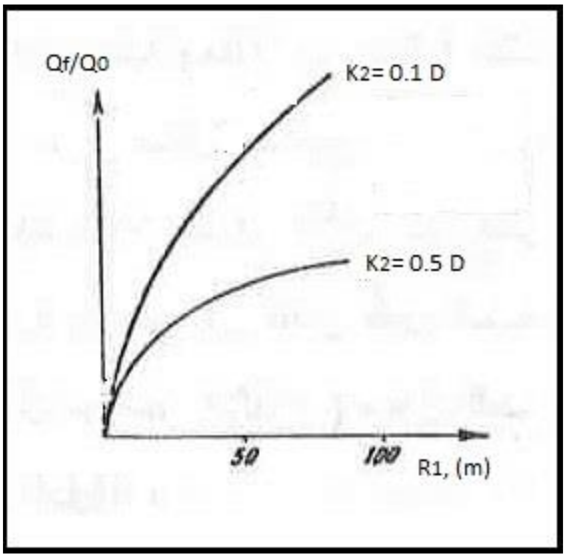


Figure 9: Fracking efficiency VS rock initial permeability

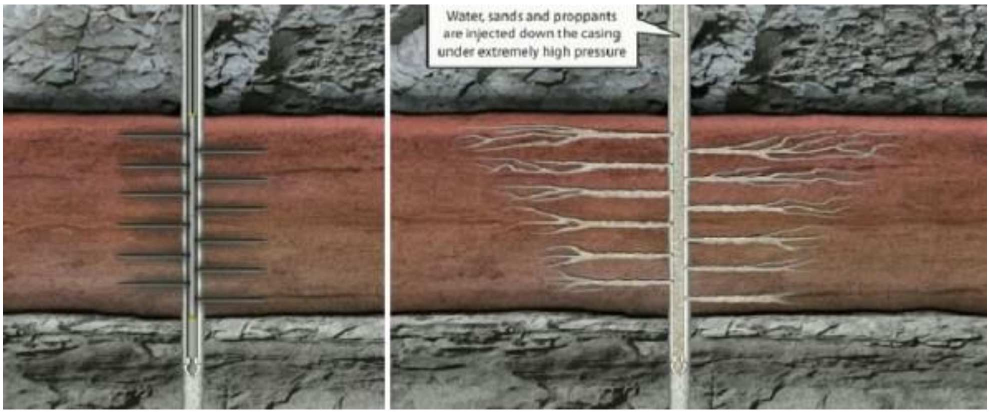


Figure 10: Fracking through perforation holes

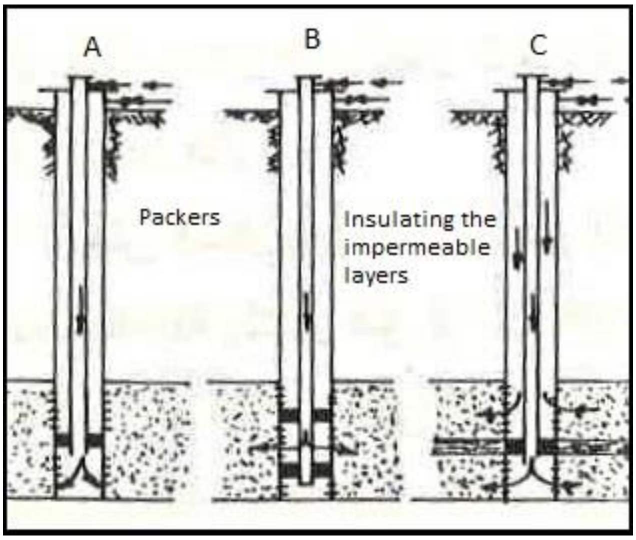


Figure 11: Separated hydraulic fracturing

Acknowledgments

My thanks and gratitude are to my wife Rasha, my son George Alexander, and my daughter Tia for their love and support.

References

[1] Bob L. Haney, D. A. (1997). The Application of an Optimized Propellant Stimulation Technique in Heavy Oil Wells. International Thermal Operations and Heavy Oil Symposium, 10-12 February, Bakersfield, California, 1-12.

[2] Clarke, C. P. (2015, 12 1). Does hydraulically fracturing – or fracking – shale rock have the potential to cause methane contamination of groundwater in England? Retrieved 10 10, 2018, from https://phoenixsic.wordpress.com/author/phoenixsic/

[3] Hamoud, A. S. (1995). Enhanced oil recovery in carbonate reservoirs. Hims: AlBaath university.

[4] Erick Galante, A. H. (2013). International Journal of Oil Gas and Coal Technology. International Journal of Oil, Gas and Coal Engineering., 1-7.

[5] Nasour, T. (1991). Reservoir and production engineering (1 ed.). Hims: Albaath university.

[6] Gandossi, L., & Von Estorff, U. (2016). An overview of hydraulic fracturing and other formation stimulation technologies for shale gas production. Scientific and Technical Research Reports, 1-3.

[7] Arrell, J. (2014, February 8). ATK Company Overview & Experience with Propellant Well Stimulation. Retrieved 10 10, 2018, from http://www.mde.state.md.us/programs/Land/mining/marcellus/Documents/140210_ATK_Overview%20_Propellant_Stimulation.pdf

[8] Donaldson. (1985). Enhanced oil recovery, Fundamentals and Analysis. Oklahoma, USA.

[9] George King. (2012). Hydraulic fracturing 101. SPE, 1-20.

[10] Charez, P. A. (1997). Rock mechanics. University of Minnesota.

[11] Clark, J. P. (2013). Emulsions: When Oil and Water Do Mix. Institute of Food Technologists, 1-12.

[12] Shafeeq Khan, L. S. (2018, January 2). Engineered Friction Reducers Enhance Proppant Transport. Retrieved from Hartenergy: https://www.epmag.com/engineered-friction-reducers-enhance-proppant-transport-1676866

[13] Mader, D. (1989). Hydraulic Proppant Fracturing and Gravel Packing. Elsevier.