THE BASICS OF SLICKWATER FRACTURING

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ABSTRACT
Slickwater Fracturing has enabled us to penetrate deeper into tight formations than ever before. This presentation will discuss the basic fundamentals of Slickwater fracturing with respect to the base fluid, chemical additives, the frac process, the advantages and disadvantages of Slickwater, proppant placement, proppant selection, and Slickwater frac candidates. We will also give a brief description of the Equipment requirements to perform a Slickwater frac successfully and safely. By providing this information we will aid in the understanding of how Slickwater transports proppant and places this proppant in the fracture.

INTRODUCTION

This paper will discuss how the industry evolved from the early Oil Fracs to the Slickwater Fracs of today. We will discuss the Chemical makeup of a Slickwater frac and how they are different from other fluids we use in fracturing throughout the industry. We will show the properties of these fluids and why they should be implemented in tight or compartmentalized formations. We will identify which candidates should be considered for fracs and refracs. Through the discussion of the paper we will describe the different types and sizes of the proppant used in these Slickwater fracs and the properties they possess to make them optimum for Slickwater fracs. The proppant placement is very different in Slickwater fracturing and we will discuss how this occurs in the formation. Slickwater frac jobs usually require more equipment then typical frac jobs and we will give examples and try to describe their function.

FRAC FLUIDS OF THE PAST

Hydrocarbon Fracs

These were the very first fracs that were used. They consisted of using gelled gasoline, crude oil or diesel oil. They transported sand for proppant reasonably well, but they were usually very small jobs. They may have only used 50 sacks of sand. Viscosity was increased later by emulsifying the hydrocarbon fluid with water or various types of acids. These fracs had very little penetration in the zone. The theory behind these types of fracs was they were more compatible with the formation then aqueous fluids. So they were popular for quite some time. They are still used today, but diesel fuel is banned from fracturing.

Linear Gel Fracs

These fluids consist of Guar Gel being mixed in water at various amounts from 10 lbs. to 60 lbs. of gel per thousand gals of water. This will usually result in a fluid with viscosities ranging from 6 cps. To 55 cps. These fluids are far less dangerous than the hydrocarbon fracs and the viscosities were far more predictable then crude oil.

Crosslinked Fracs

In the 80’s crosslinked fracs became the rage. We could transport high concentrations of proppant with almost no worries of screen out. The conductivity and retained permeability in these fracs were a great step forward. We are actually suspending the proppant in the frac fluid for the entire frac procedure. This was like having pieces of fruit suspended in your Jello at lunch. Borate, Zirconate, and Titanate cross linkers were very popular for the next 20 years, but breaking these crosslinked gels could be a challenge especially in low temperature formations. This unbroken gel and the residue from gel could impede permeability.

Slickwater Fracs

Variations of today’s Slickwater fracs were used when Gel fracs were pumped years ago, but they usually were so small, that they were not real effective for serious stimulation. They usually were just light loadings of gel to cut the friction pressure of the tubing or casing we were pumping down. We now use Friction reducer chemical rather than powdered guar. We have gone to Slickwater fracs to try to stimulate the zone further down the developed fracture than ever before without damaging these tight matrixes with complex fluids. The proppant concentrations are not nearly as great, but the benefits of a long fracture outweigh the increased conductivity of enormous amounts of proppant in tight or compartmentalized rock. In this case more geometry is more important than conductivity.

Hybrid Fracs
These are a combination of the Gel Fracs and the Slickwater Fracs. We tail in the last portion of the Slickwater frac with the crosslinked or liner gel at a higher concentration allowing for greater conductivity near the wellbore.

SLICKWATER CHEMISTRY
Base Fluid
The base fluid for a Slickwater frac consists of fresh or produced water. The water is tested to make sure all chemicals perform as they should and also to optimize the mixing rates as to use no more chemical than needed to complete the job. Produced water may have to be filtered or treated before it is acceptable for fracturing.

Friction Reducer
FR is a synthetic acrylamide copolymer surfactant in a mineral oil base fluid. This chemical can reduce friction pressure as much as 75% depending on mixing rates. The use of this chemical will result in a viscosity of 2-3 cps. A Slickwater breaker is recommended. (Fig. A)

Nano Surfactants
Will reduce the interfacial tension between water, oil, gas and the formation. This will allow for better water flow and recovery of the fluids from the well. This surfactant has Nano technology which has a smaller molecule that results in deeper penetration into the matrix pore space, making it more efficient for fluid removal than previous surfactants.

Slickwater Breaker
Slickwater breaker is a strong oxidizing breaker. Synthetic polymers can be very hard to break. Therefore a strong oxidizing chemical is needed to break the chemical chain. This breaker degrades the polymer and returns the viscosities to essentially that of the base water within 18 hours at a temperature as low as 90 degrees. Therefore breaker will reduce damage and help retain frac conductivity and permeability. Temperature and pump time dictate how much breaker is required.

KCL Substitute
This is a highly concentrated liquid potassium chloride substitute. It is used to maintain a chloride content in the frac fluid to keep clays from swelling and migrating resulting in reduce conductivity. KCL substitutes come in different varieties of reactivity so care should be taken in choosing the right % of KCL content one needs, rather than how many gals per thousand to use.

Biocide
This chemical gives a rapid, effective and economical control of most sulfate-reducing and slime-forming bacteria. It shows high effectiveness in penetrating biofilms and killing the bacteria beneath. Biocides prevent corrosion and also allow other chemicals to be more effective.

ADVANTAGES OF SLICKWATER FRACS
Lower Treating Pressure
The Slickwater frac fluid exerts less friction pressure on pipe than a Crosslinked frac. It also possess less drag on the formation, which makes it capable of penetrating into tight formations.

Longer Frac Length
Typically the Slickwater fracs have a lot longer frac length than a comparably cost Crosslinked frac. This extended length exposes more matrix to the fracture. It’s all about geometry.

Frac Height
Slickwater fracs with their lower viscosity stay in zone better than high viscosity frac fluids. More of the proppant will stay in the pay zone and less water may be produced in some cases.

Dissolves Formation Salts
Fresh water with KCL substitute has the ability to absorb formations salts which can improve permeability when the fluid is recovered.

Less Gel Damage
Slickwater is less damaging than Gel Fracs.

Economical
Per gallon the Slickwater frac is more economical than any other frac fluid in the industry even though it may require more horsepower to achieve.

Complex Fracture Network
The Slickwater frac usually contains a large fracture with many small fractures emerging off of it, to make contact with more matrix than a typical Gel frac.

Monolayer Proppant Pack
Partial monolayers of proppant are possible in these small fractures with less concentrations of proppant. Monolayers of proppant have immense permeability properties as long as embedment of the proppant is not a factor, which is not usually the case in tight formations.

Water Recycling
We are able to reuse the water out of Slickwater frac for the next frac very easily since we do not have all impurities that a Crosslinked fluid may possess.

DISADVANTAGES OF A SLICKWATER FRAC
Horsepower Requirements
Slickwater fracs usually require more horsepower than traditional Crosslinked fracs. You may need anywhere from 8 to 20 Frac pumps on location depending on rate and pressure. There are two reasons for this. We are fracing a tighter formation than other frac fluids are able to, which will mean excessive pressure or we need more rate to keep the frac open due to leak off once the frac has been initiated. Velocity is the key to transporting proppant on a Slickwater frac as opposed to viscosity on a gelled frac.

Frac Width
The frac width of a Slickwater frac is narrower than that of a high viscosity fluid, so high concentrations of proppant will not fit. Also smaller sized proppants need to be used in Slickwater fracs. Proppant will also settle in the fracture on a Slickwater frac.

Water
More water is needed for most Slickwater fracs versus Crosslinked fracs because of the leak off and the amount of length desired to be an effective frac.

Equipment Footprint
With the addition of more frac pumps, we need more room than a Crosslinked frac. So the industry is always trying to limit the amount of space we take by going to vertical Sand Stands and Juice Tanks from a centralized water source.

Recovery Fluid
With the addition of more fluid in our Slickwater fracs to achieve longer lengths, we must deal with more recovery fluid than ever before. We can use this water for the next frac by cleaning it and using it again instead of hauling it to a disposal well.

CANDIDATES FOR SLICKWATER FRACS
Tight Formations
Formations such as shales, tight dolomites, and dense limestone are good lithology candidates for Slickwater fracs.

Low Water Saturation

Formations with low water saturation are better suited for Slickwater fracs, but does not limit the use of these fracs if you have the infrastructure in place to dispose of large amounts of water.

Compartmentalized Formations

Formations that do not seem to be drained by nearby production. They seem to have no correlation to the pressure of other wells in the field.

Successful Formations

Slickwater fracs have been very successful in the Mississippi, Viola, Conglomerates and many different Shales. We are trying new formations all the time. Even in old fields where wells have been producing for over 35 years. Refracs have been successful in exposing virgin reserves.

PROPPANT SELECTION (SIZE)

100 Mesh, 30/50 and 40/70 Proppants

These smaller proppants are <1/100th of an inch, 1/30th – 1/50th of an inch and 1/40th – 1/70th of an inch in diameter. These are popular in tight zones using Slickwater frac fluid on Vertical or Horizontal wells depending on the type of formation being frac'ed.

20/40 Proppant

1/20th – 1/40th of an inch in diameter. This proppant is used more in Horizontal wells. Not so much in Shale formations.

16/30 Proppant

1/16th – 1/30th of an inch in diameter. This proppant is not usually used in Shales. Primarily you would use this proppant in Oil bearing Cherts, Limestones, and Dolomites. It requires more frac width than the smaller proppants and is used at the tail of a frac.

16/30 Resin Coated Sand

Resin Proppant is quite popular in Vertical wells as well as some Horizontals. We use this proppant at the tail of a frac to help consolidate the proppant and keep it from flowing back into the well bore. Activated by chemical or temperature the proppant grains will cling together as not to migrate during flow back or production. Resin coated sand also has a higher retained permeability factor than uncoated sand due to its more spherical shape.

PROPPANT SELECTION (MAKEUP)

Brady or Brown Sand

Silica that has been weathered, but can be angular in shape and has more inclusions or natural cracks that make it weaker in high closure formations. This proppant is usually limited to 4,500 psi closure stress.

Ottawa or White Sand

Silica that has been extremely weathered to the point where it is more spherical in shape than Brown sand and is stronger with less inclusions. This proppant is usually used up to 6,000 psi closure stress.

Resin Coated Brady or Ottawa Sand

This is a tail in Sand that is precoated with resin, and is activated by chemical or temperature to cause the grains to cling together to eliminate flow back of proppant. This proppant can be made with either Sand to handle a wide range of closure stresses. Typically Resin Coated sand has more retained conductivity than noncoated sand.

Ceramic Proppants

There is a whole field of manufactured proppants in the industry that are used when closure stress exceeds 8,500 psi. They are very spherical in shape. So they're permeability numbers are great. These proppants can be very expensive to pump.

SLICKWATER PUMP SCHEDULE

Breakdown Stage

Usually we will pump a breakdown fluid consisting of 7 ½%- 15% HCL Acid to open the perforations further or clean up mud around a sliding sleeve in a Horizontal.

Pad Stage

This stage consists of straight Slickwater without proppant. This stage is a fluid loss buffer to open the fracture. We will try to reach our maximum rate with this stage. The Pad stage usually is 10%-20% of the total volume of the frac job. It is important that the Pad stage is large enough to avoid screen out.

Proppant Stages

Proppant stages start after the Pad stage. We will start at .2 ppg or less and gradually work our way up to 1.5 ppg in 1/10th or ¼ ppg increments depending on the application. We will tail in with a larger proppant and a Resin Coated sand if the formation will allow us to. We always like to make our stages large enough that we can see how one stage is reacting in the formation before starting the next stage.

Flush Stage

This is the final stage to clear all the pipe of proppant. We do not want to over flush the pipe more than necessary. This can impede near well bore permeability.

SLICKWATER FRAC PROPPANT PLACEMENT

Velocity

As we spoke of before, Slickwater fracs transport proppant with velocity of the fluid versus supporting the fluid in a Crosslink frac.

Settling Rate

The settling rate of proppant in a Slickwater frac is very quick, so we are actually banking the proppant in the fracture like dunes of sand in the desert. We need this fluid velocity to place this proppant further down the fracture.

Different Sized Proppant Placements

The proppant immediately begins to settle until an equilibrium height is reached and subsequent proppant stages will be deposited near the back of the existing dune farthest from the well bore. This leaves a layer of the last proppant from the wellbore to the tip of the fracture.

The first proppant (usually 30/50 or 40/70) remains closest to the well bore.
Tailing in with 16/30 proppant after the 30/70 erodes part of the first bank and drifts the 30/70 further down the fracture away from the well bore.

The result, is a more permeable proppant pack reaching further than we have ever propped before. (Fig B) vs. (Fig C)

FRAC EQUIPMENT REQUIREMENTS

Frac Pump Unit

These pumps are higher horsepowered (2,000 – 3,000 hhp) as compared to years ago, to try and limit the size of the foot print needed to set up on a location. Most Slickwater fracs of today incorporate Quituplex pumps (5 plunger) instead of triplex pumps (3 plunger) for more rate and reliability.

Blender Unit

The Blender is where all the action takes place. This is where the water gets sucked up and induced with the frac chemicals we talked about. We auger the proppant into the Blender tub from our sand storage unit and then super charge this frac slurry to the Frac Pumps at a minimum of 35 psi. at a rate of up to 120 bpm per blender unit.

Computerized Chemical Add Unit

This Additive unit measures and pumps the chemicals at a closely monitored rate. The computer is able to change the rate of all the chemicals based on the slurry rate, weather we decrease or increase the rate.

High Pressure Missile

The high pressure missile allows us to eliminate the use of excessive iron and suction hoses while also being able to isolate each pump with a closing valve should there be some sort of failure.

Proppant Storage

The Frac Packs or Sand Kings can store sand for smaller jobs, but for larger stage jobs companies will incorporate the use of portable vertical sand stands. They hold much more proppant than a single Frac Pack and take far less space. They have built in scales to monitor sand usage for quality control and avoiding sand shortages.

Computerized Frac Monitoring Van

The vans of today have about every option to maintain comfort on large stage jobs. We monitor rate, pressures, time, chemical additives proppant usage, density, and display a wide range of charts or models the customer may require, as well as provide post frac data. The Frac van controls all the pumps from one console. We monitor the engines, transmissions, and pumps at a distance for safety of all individuals on location.

Quality Control Van

This van is used to check the quality of the frac slurry. We monitor viscosity, proppant, and the amount of chemical being used as well as an inventory of all materials.

Iron Truck and Crane

The Iron truck is used to assemble the iron to eliminate any injuries to our employees.

Tethering Lines

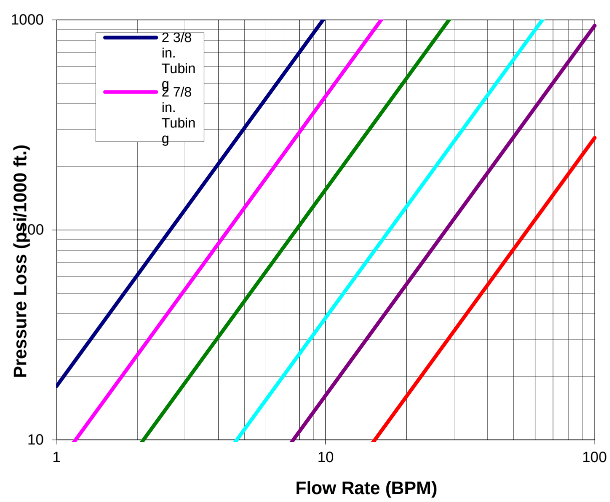
The iron is secured by tethering lines to mitigate the risk of lines failing and parting, causing injury to anyone on location. Safety is paramount.

CONCLUSIONS

Slickwater Fracturing will enhance more drainage area for the dollar than any other form of fracturing technique used today in tight formations.

Friction Pressure

Fresh Water



Slick Water
1.0 Gal WFR-1

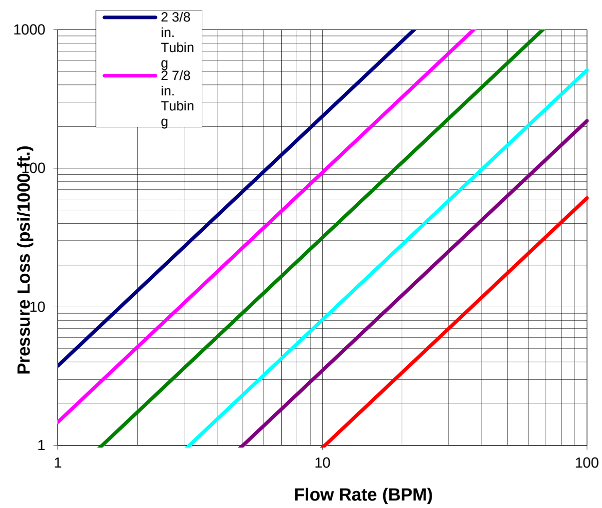
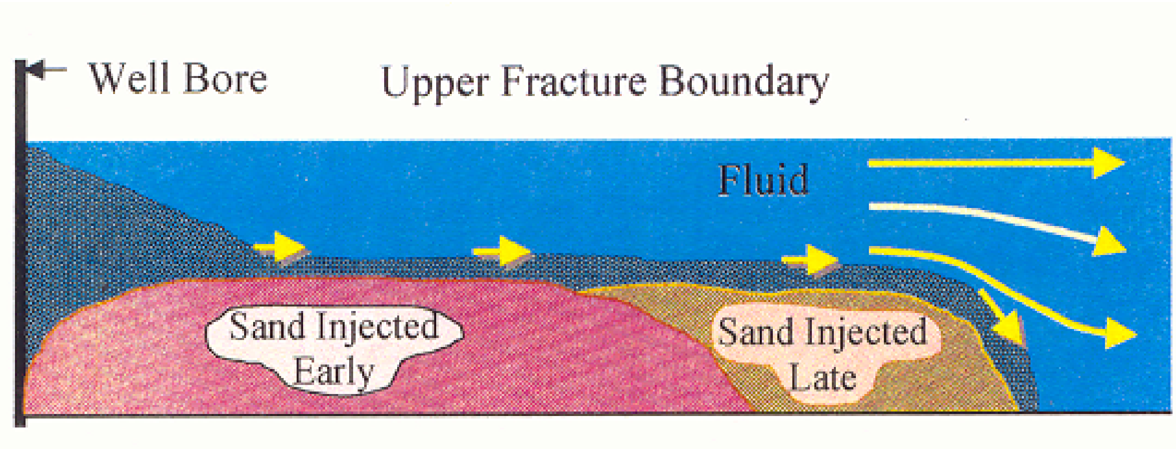


Figure A

Slickwater Proppant



- **Proppant transportation and deposition conceptualization by Patankar, N.A. *et al*: *"Power Law Correlations for sediment Transportation in Pressure***

Figure B

Crosslinked Proppant

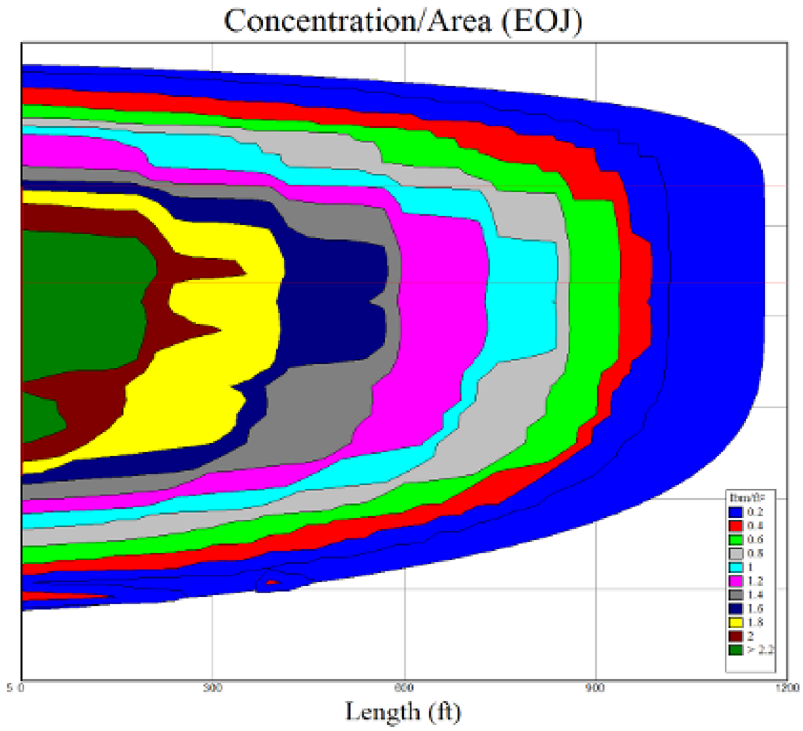


Figure C