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Study on Fracturing Fluids System in Hydraulic Fracturing Treatment

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Abstract- **Fracturing fluid is the most dominant factor in hydraulic fracturing treatment. The efficiency of fracturing treatment is much more dependent on the proper selection of the fracturing fluids. When fracturing takes place, viscosity plays a most important role in providing required fracture width to ensure proppant entrance in to the fracture, carrying the proppant from the wellbore to the fracture tip, generating a desired net pressure to control height growth and providing fluid loss control. The fluid that is used to create the desired viscosity must be safe to handle, environmentally friendly, non-damaging to the fracture conductivity and reservoir permeability, easy to mix, inexpensive and able to control fluid loss. This is a very important list of requirements that has been recognized since the beginning of Hydraulic fracturing. In this paper there will be discussed on the history of fracturing fluids, the engineering requirement of a good fracturing fluid, the types of fracturing fluids and also the types fracturing fluid additives used in fracturing treatment.**

Index terms- **Breakers, Clay Stabilizers, Fluid-Loss Additives, Guar, Oil-Based Fracturing Fluids, Surfactants, Water-Based Fracturing Fluids**

I.INTRODUCTION

The fracturing fluid is the most vital and critical component of the hydraulic fracturing treatment. The main functions of the fracturing fluids are to open the fracture and to transport proppants along the length of the fracture. The successful hydraulic fracturing treatments require that the fluids exhibit some special properties. In addition to exhibiting the proper viscosity in the fracture, they should break and clean up rapidly once the treatment is over, provide good fluid-loss control, exhibit low friction pressure during pumping and be as economical as is practical. More than 90% of fracturing fluids are water-based. The main reason is that aqueous fluids are cheaper and can provide better control of a broad range of physical properties as a result of additives developed over the years. Fracturing fluid systems should possess high viscosity but low friction properties. If the fracturing fluid cannot be pumped down small tubular goods easily, the fluid normally is not acceptable as a fracturing fluid. A fracturing-fluid should be able to maintain the designed viscosity at bottom hole temperature. A fluid which rapidly loses its viscosity due to thermal thinning or degradation is not acceptable for treatment of high-temperature wells. Therefore fracture-fluid stability at high temperature is very critical. Finally, fracturing fluids should be cost-effective. So economic analysis need to be conducted prior execution comparing the cost and gain.[1]

II. HISTORY OF FRACTURING FLUIDS

The initial hydraulic fracturing solutions were oil-based which included the crude oil and gasoline thickened with napalm. About 92 percent of the nearly 24,400 early treatment fluids reported in the IHS database were listed as “unknown” before 1953. Water was introduced as a fracturing fluid in 1953. Shortly thereafter, other water-based fluids including unique service company formulations such as My-T-Frac also increased. The number of records of proppant use, and of sand in particular, also increased around 1953. Proppants are indicators of hydraulic fracturing and sand is often regarded as the most common proppant. From 1953 through 1999, nearly 992,300 hydraulic fracturing treatments were applied in large measure to vertical oil and gas wells. The years between 2000 and 2010 gave rise to notable changes in hydraulic fracturing treatment fluids and additives in nearly 749,000 treatments reported in the IHS database. Between 2007 and 2009, significant shale gas production began in states outside of Texas, as reflected by the spike in the number of hydraulic fracturing treatments. This increase in hydraulic fracturing treatments around 2008 is also consistent with the emergence of "slick water" formulations as well as the increase in surfactant additives added to water to create the slick water treatment fluid type. Slick water is a fluid type used in hydraulic fracturing and is mostly water (approx. 99 percent) with additives namely friction reducers, surfactants, and possibly other contents such as polyacrylamide, biocides, electrolytes, and scale inhibitors in variable quantities that increase fluid-flow velocity and sand transport through the borehole casing and delivery into the formation at depth.[2]

III. ENGINEERING REQUIREMENTS OF A GOOD FRACTURING FLUID

The fracturing fluid must have certain physical and chemical properties to achieve successful stimulation.[3]

- It should be compatible with the formation material.
- It should be compatible with the formation fluids.
- It should be capable of suspending proppants and transporting them deep into the fracture but should not carry it back during flow back.
- It should be capable through its inherent viscosity to develop the necessary fracture width to accept proppants or to allow deep acid penetration.
- It should be an efficient fluid (i.e. have low fluid loss).
- It should be easy to remove from the formation.
- It should have low friction pressure.
- Preparation of the fluid should be simple and easy to perform in the field.
- It should be stable so that it will remain its viscosity throughout the treatment.
- The fracturing fluid should be cost-effective.

IV. TYPES OF FRACTURING FLUIDS

Since reservoir stimulation varies in temperature, permeability, rock composition and pore pressure, many different types of fluids have been developed to provide the properties described above. The following fluids are usually used for hydraulic fracturing: [1]

a. Water-Based Fracturing Fluids.
b. Oil-Based Fracturing Fluids.
c. Alcohol-Based Fracturing Fluids.
d. Emulsion Fracturing Fluids.
e. Foam-Based Fracturing Fluids.
f. Energizing Fracturing Fluids.

A. WATER-BASED FRACTURING FLUIDS

Water-based fracturing fluids have many advantages over oil-based fracturing fluids. They are:

- Water-based fluids are economical.
- Water-based fluids yield increased hydrostatic head compared with oil, gas or methanol.
- Water-based fluids are incombustible. So they are not a fire hazard.
- Water-based fluids are readily available.
- Water-based fluids are easily viscosified and controlled.

The water based fracturing fluids are also categorized as following:

1. Linear Fracturing Fluids.
2. Crosslinked Fracturing Fluids.
3. Delayed Crosslink System.

1) Linear Fracturing Fluids:

Linear fracturing fluids are fracturing fluids without chemical crosslinked structures. The main purposes of using these fluids are to thicken water to help transport proppant, to decrease fluid loss and to increase fracture width was apparent to early investigators. Starch had been used as the first water viscosifiers to thicken and to decrease the fluid loss in drilling mud. The reasons behind the short life of this fluid were shear sensitivity, lack of temperature stability and bacterial degradation. It was replaced by guar gum in the early 1960's. The guar polymer comes from a bean. It thickens and viscosifies the fluid when added to water. Other linear gels used today as fracturing fluids are hydroxypropyl guar (HPG), hydroxyethylcellulose (HEC), carboxymethyl HPG (CMHPG), xanthan gum, and in some rare case polyacrylamides.

2) Crosslinked Fracturing Fluids:
Crosslinked fracturing fluids were considered a major advancement in hydraulic fracturing technology. Crosslinked fracturing fluids eliminated many of the problems when fracture-treating deep hot reservoir using linear gels. In order to achieve deep penetration of proppant or of acid away from the wellbore, the higher viscosity crosslinked fracturing fluids are the better option. The earliest crosslinkers were borates and antimony metal crosslinkers. The borate fracturing fluid was a high pH-system typically in the pH 10 range while the antimony was approximately pH 3-5. The first crosslinked fluid was a guar gum system. Many other crosslinker systems have been developed such as aluminium, chromium, copper, manganese, titanium chelates, and zirconium chelates. Crosslinking the polymer molecule tends to increase the temperature stability of the base polymer. Crosslinking fluids have the tendency to lose viscosity permanently as a result of high shear rates. As a result the uses of standard crosslinked gel systems have declined and have been replaced by delayed crosslinked fracture-fluid systems.

3) Delayed Crosslink System:
A delayed crosslinked system allows better dispersion of the crosslinker as well as yields more viscosity and improves fracturing fluid temperature stability. The gel stability is a direct function of crosslinking at low shear rates. Examples of delayed crosslinking additives are glyoxal, keto aldehydes, hydroxyl aldehydes, glycols and glycerol. Glycols and glycerol can delay the crosslinking of borate in hydraulic fracturing fluids based on galactomannan gum. In this case, the initially formed borate complexes with low molecular weight are exchanged slowly with the hydroxyl groups of the gum which cause delayed crosslinking.

The main advantages of using a crosslinked fluid than a linear fluid are:

- Much higher viscosity can be achieved in the fracture with a comparable gel loading.
- The system is more efficient in fluid loss control.
- A crosslinked fluid has better proppant-transport capabilities.
- A crosslinked fluid has better temperature stability.
- A crosslinked fluid is more cost-effective per pound of polymer.

B. OIL-BASED FRACTURING FLUIDS
Using oil-based fracturing fluids is advantageous in certain situations to avoid formation damage to water-sensitive oil-producing formations that might swell if water is introduced. The primary disadvantage of using oil-based fracturing fluids is the fire hazard. Another disadvantage of an oil-based fluid is the higher pumping friction than a delayed crosslinked water-based fluid system. Pumping pressures are also higher due to lack of hydrostatic head of the hydrocarbon compared with water. The preparation and quality control of gelling crude oil requires much more carefulness than those of water-based fluids.

C. ALCOHOL-BASED FRACTURING FLUIDS
Alcohol has frequently been used for the removal of water blocks because alcohol reduces the surface tension of water. In fracturing fluids, alcohol is widely used as a temperature stabilizer because it acts as a hydrogen scavenger. Methanol based fracturing fluids particularly at higher concentrations present difficulty in the controlled degradation of the base fluid. Very high concentrations of any type of breaker are required for complete degradation. The primary benefits of methanol relate to low surface tension, miscibility with water, removal of water blocks and compatibility with water-sensitive formations.

D. EMULSION FRACTURING FLUIDS
The two basic types of oil or water emulsions are oil external and water external. An oil external emulsion is a two-phase system where oil is the continuous phase and water is emulsified in the oil. A water-external emulsion has water as continuous phase and oil as the discontinuous phase. Water-external emulsions have lower friction pressures because of the low viscosity of water compared with oil. There is a tendency to achieve friction reduction with the polymers in the water phase of water-external emulsion. The pumping pressures of the water external emulsions are somewhat higher than for typical conventional crosslinked fracturing fluid but much lower than the oil-external emulsions.

E. FOAM-BASED FRACTURING FLUIDS

Foam fracturing fluids are simply a gas-in-liquid emulsion. The gas bubbles provide high viscosity and excellent proppant transport capabilities. A stable foam has viscous properties similar to a gelled, water-based fluid. The volume of gas necessary to create a stable foam is approximately 60 to 90% of the total volume at a given temperature and pressure. This gives that 60 to 90% of the fracturing fluid is gas. Gas bubbles are generated by turbulence when liquid and gas are mixed. However, foam based fracturing fluids have several disadvantages. Extensive care should be carried out in running a foam fracturing treatment from a mechanical point of view. Small variations in the water or gas mixing rates can cause the loss of foam stability. Pumping pressures will be large compared with gelled water. Moreover it is very difficult to get high sand concentrations in foam fracturing.

D. ENERGIZING FRACTURING FLUIDS

A fluid is energized by adding a gas component into the fracturing fluid. The advantages of energizing fracturing fluids are quite obvious, particularly for a formation with low bottomhole pressure. The energy imparted by the gases enables more rapid removal of the stimulation fluid. Entrained gas is also beneficial for fluid-loss control. The incorporation of inert gases into a fracturing fluid will yield proportionally better fluid efficiency than the same fluid without the entrained gases. The type and characteristics (i.e. solubility) of gas used for energizing a fracturing fluid should be considered carefully. Dissolved gas does not easily dissipate into the formation. When the pressure is subsequently reduced during flowback, the dissolved gas will begin to evolve from the mixture and to impart a solution gas drive to the treating fluid. This gas-drive phenomenon results in effective removal of the treating fluids from the reservoir. It is therefore imperative that a fluid commingled with a gas should be flowed back as quickly as possible.

V. FRACTURING FLUID ADDITIVES

The main purposes of using additives for fracturing fluids are to increase the fracture creation and proppant carrying capability and to reduce formation damage.[1]

1) Biocides: A biocide is an additive to maintain gel stability of fracturing fluids on the surface and to protect the formation from bacterial attack. An example of a biocide is mercaptobenzimidazole.

2) Breakers: A breaker is an additive that enables a viscous fracturing fluid to be degraded controllably to a thin fluid that can be produced back out of the fracture. All the breaker systems are used to degrade the polymers in water-based fracturing fluids. Common breakers are enzymes, oxidative and catalyzed oxidative breakers.

3) Buffers (pH Control Additives): Buffering agents are used in fracturing fluids to adjust and maintain the pH. It also speeds up or slows down the hydration of certain polymers. It can be salts of a weak acid and a weak base. Typical products are ammonium, potassium, sodium bicarbonate, fumaric acid, combinations of mono and disodium phosphate, soda ash, sodium acetate or combinations of these chemicals. Another function of a buffer is to ensure that the fracturing fluid is within the operating range of the breakers or degrading agents. Some breakers simply do not function outside specific pH ranges.

4) Surfactants and Nonemulsifiers: Surfactant can act as demulsifiers or as emulsifiers because of their surface-active nature. Some fracturing fluids are composed of hydrocarbon and water that are emulsified to build fluid viscosity. If emulsified fluids are used, it is desirable for the surfactant to adsorb on the formation so that the emulsion will break. Another function of surfactant is to prevent or to treat near-wellbore water blocks. Surfactants lower the surface tension of the water and reduce capillary pressure which results in lower energy required to move the water across boundaries and through the formation matrix.

5) Clay Stabilizers: Clays and fines present in producing formations may reduce stimulation success. Damage can be mitigated through the use of clay-stabilizing agents. The common clay stabilizers are potassium chloride, ammonium chloride, calcium chloride, and polymeric clay stabilizers.

6) Fluid-Loss Additives: To obtain excellent fluid-loss control, one must have not only a bridging material but also a wall-building material. The common fluid-loss additives are guar gum, silica flour, diesel fuel, calcium carbonates and lignosulfonate, and natural starch.

7) Foamers: Virtually any base fluid can be foamed with a temperature-stable foaming agent. Therefore it is desirable to determine that there is no problem with stability of the foamer during the treatment. Common stabilizers for foaming treatments are the basic guar, hydroxypropyl guar (HPG), and xanthan gum which are added to the fracturing fluid to increase the foam half-life, particularly at elevated temperature.
8) Friction Reducers: The most efficient and cost-effective friction reducers used for fracturing fluids are low concentration of polymers and copolymers of acrylamide. These friction reducers are applicable in water and acid systems. High turbulence has to be achieved for the friction reducer to be advantageous and neither the low-rate casing treatment nor the viscous fluid can be assisted by friction reducers.
9) Temperature Stabilizers: Temperature stability of fracturing fluids is basically a result of the stability of the base chain polymer, the pH of the fracturing fluid and the presence of oxidizing agents. One basic use of stabilizing fracturing fluids is to increase the pH into the basic range which is from 8 to 10. Another basic use for temperature stabilizing is removing free oxygen from the system.
10) Thickener: Polysaccharides and their derivatives form the predominant group of water soluble species generally used as thickener to increase viscosity of treating fluids. The increase in fluid viscosity is needed to improve proppant placement and fluid loss control. Examples of thickener are hydroxypropylguar, galactomannans, hydroxyethylcelloluse, carboxymethylcellulose, reticulated bacterial cellulose, and xanthan gum.

VI. CONCLUSION

From this study it is clear that fracturing fluids hold the significant portion of the fracturing treatment. So to get a better result from the fracturing treatment there should be a great concern of selecting proper fracturing fluids with respect to the formation requirements. Moreover, there should be most concern about the fracturing fluid additives for better performance of fracturing fluids.

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