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OVERVIEW OF ISSUES RELATED TO MIXING CO_2 AND PROPPANT IN THE METHOD OF GAS EXTRACTION FROM SHALE ROCKS

1. INTRODUCTION

Nowadays, there is a need to improve energy production. An increase of energy generation is possible by exploitation of unconventional hydrocarbon deposits (gas from coal, tight gas, shale oil and gas). A popular method used to extract gas from shale is hydraulic fracturing, which is not, however, effective enough in case of some deposits. If geological conditions are more complicated, there is a need to find another fracturing medium. Carbon dioxide is becoming more and more frequently used. At normal temperature and pressure, CO_2 is a gas, however, under wellbore conditions (at the depth of 1000 meters, where high pressure and temperature occur), it becomes the supercritical phase which is an intermediate phase between a liquid and gaseous state.

Proppants are indispensable elements of fracturing. The main purpose of their application is to block closing the fracture when the fracturing pressure is reduced. It allows, the fractures to be open all the time and the flow of hydrocarbons is possible. Proppants was used for the first time at the end of 1940s in the USA. At the beginning, there was used quartz sand, however, his low strength to compression and a non-spherical shape contributed to invention of new material for proppants. There were attempts to extract gas from deeper layers, therefore, proppant with better properties was needed. Limestone, magnesium, silica and even a nutshell were used as proppants. Many tests and research led to invention of a new generation of proppant, which is made of ceramic material. Such a kind of proppant is shown in Figure 1 [1].

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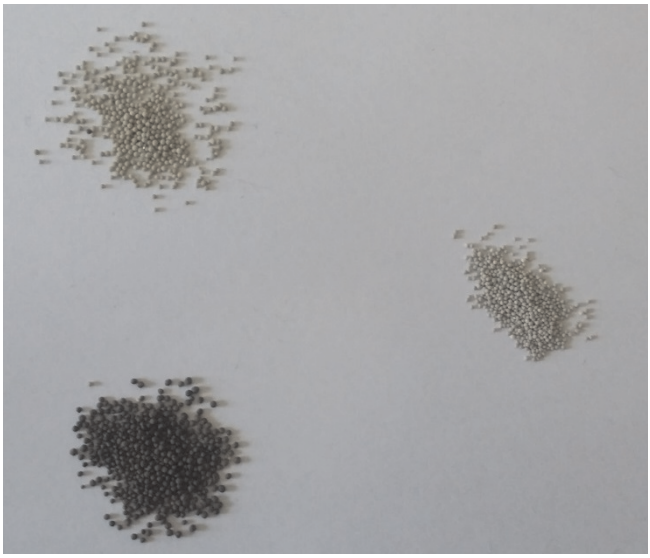

Fig. 1. Sizes of proppants grains

The usage of liquid carbon dioxide and nitrogen to rock fracturing is a well know technology. This fracturing medium is used for rocks with low permeability and eliminates a problem of removing the fracturing liquid from fractures. Moreover, it reduces the effect of rocks swelling. The use of carbon dioxide is more expensive than the use of water, however, modification of the system is not necessary.

The purpose of this paper is to present the methods of mixing proppant and liquid carbon dioxide. There are two ways to add proppants to a liquid medium. The first one is addition of proppant into a liquid, such as water or water gel and then mixing this solution into the stream of liquid CO_2. In the other method, carbon dioxide is mixed directly with proppant, without using auxiliary substances.

2. PROPPANT TRANSPORT

Proppant is added to liquid carbon dioxide to improve efficiency of the fracturing process. They help to keep the fracture open, which naturally tends to close up. Figure 2 shows a graph of fracturing efficiency using different kinds of substances with and without proppant.

Delivery of proppants into the created subterranean fracture is a significant problem. Suspension of proppant in the fracturing fluid is very important. The nature of the flow depends on the type of a medium. Viscosity is the most important parameter to ensure good grain suspension in the fracturing fluid. For this issue, Stokes law is applied, which states that the speed of subsidence is proportional inversely to average viscosity.

Viscosity is measured by a viscometer and given by a constant shear rate. There are known many types of fracturing fluid, for example, guar-based fluid, fluids based on the cellulose and other synthetics. Further tests proved that fluid elasticity was an important parameters, too [3].

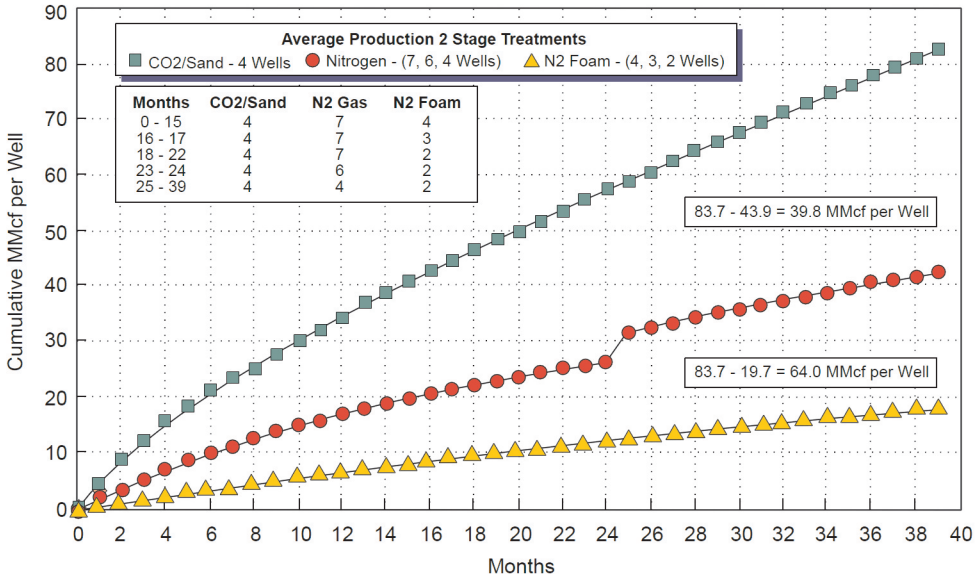

Fig. 2. Efficiency of gas production for fracturing fluid [2]

The mechanism of proppant transport in shale rocks fracturing process is different. Fracturing fluids does not have a high value of parameter viscosity and elasticity to keep proppant grains in suspension. In that case, proppant settles faster at the static conditions.

There are three mechanisms of proppant transport. When velocity of flow is very low, none or only little grains can moved. At medium velocity, proppant creeps along the surface. At high velocity, proppant grains bounce off the surface and back into the stream flow. Proppants with a significantly lower friction coefficient can be transported into deeper fractures [4, 5].

3. MIXING OF PROPPANT WITH INDIRECT FLUID

The method in which proppants are mixed with other fluid before moving to the wellbore where they are combined with the main fracturing fluid is often applied due to the fact that water has a higher value of a viscosity parameter than CO_2. In this case, uniform mixing of small particles of proppant is possible. This process is shown in Figure 3.

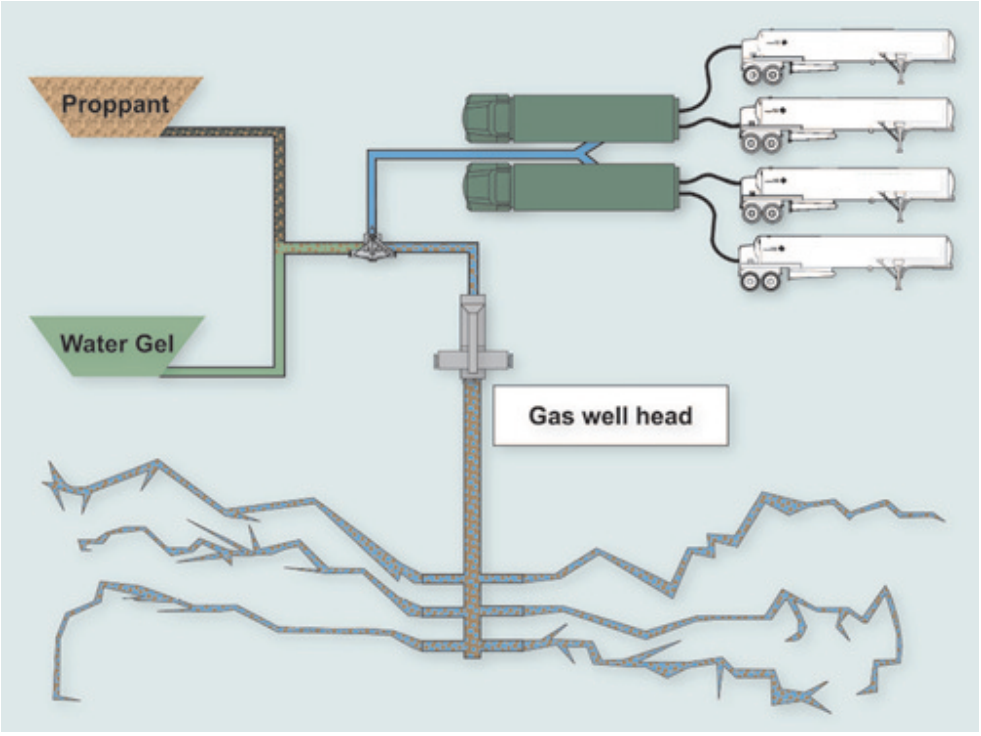

Fig. 3. Fracturing with indirect medium [6]

The issue of mixing the proppants with liquid CO_2 has been very important from the beginning of the tests of fracturing without using water. The scheme of that system is shown in Figure 4. In this solution, a blender was used for mixing gel and sand. The gel was based on 40–70% ethanol. Addition of this mixture to liquid CO_2 takes place in the wellbore.

There are a lot of indirect fluid types. Linear gel fracturing fluids are composed of polymers in an aqueous base. These polymers swell after being mixed with the aqueous solution and taking the form of gel. Other types of fracturing fluids are gelled oil fluid which rapidly develop a viscosity gel and – do not need pre-mixing. Foams are also used for fracturing, and have a wide range of viscosities and are less prone to damage to the reservoir due to small volume of water remaining in the shale. Costs of this technology are very high [8].

Blenders are key elements in this system. Their aim is mixing proppant and dry polymer or gel. In a carbon dioxide fracturing system, proppant needs to be pre-cold before being put into the blender, and water which is in a mixture freezes at low temperature. This fact complicates proppant transport since grains can block the flow. The most popular are horizontal blenders with low speed and short length of mixing shaft. Such blenders have often problems with proppant settlement and low efficiency of work. They can

mix only 0.5 m^3/min, and have 8 m^3 containers. Another truck blenders (Fig. 5) have vertical mixing containers, which solve efficiency problem. In this case, a discharge rate is 8 m^3/min, and the container volume is 25 m^3 [8].

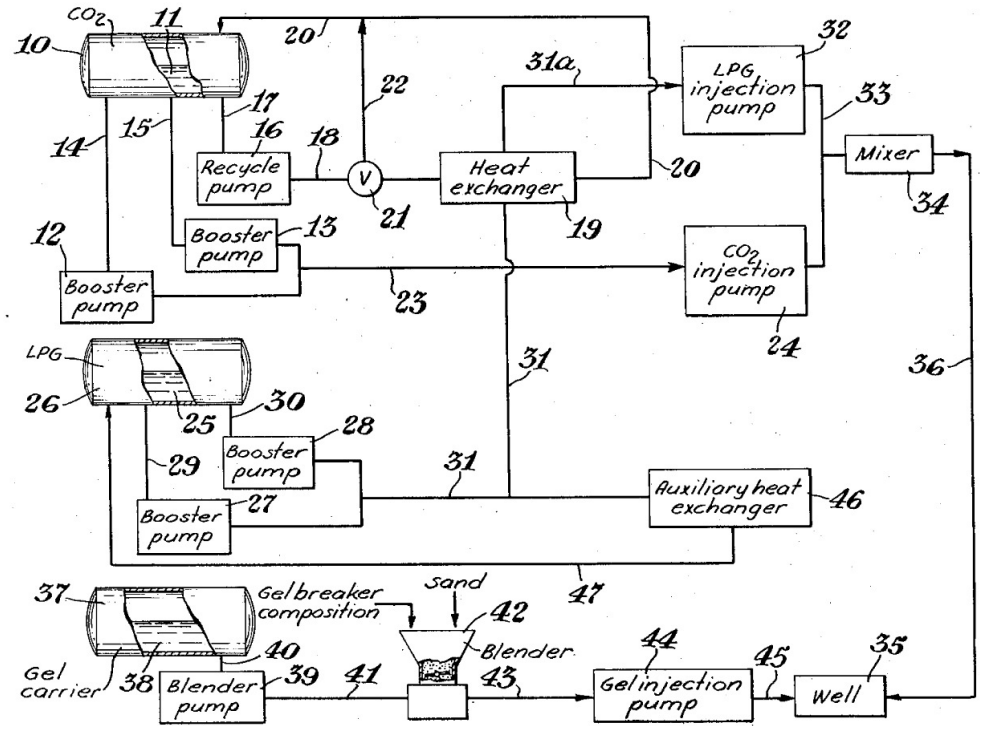

Fig. 4. Method of mixing CO_2 with proppant by W.M. Zingg [7]

Fig. 5. Mobile Track proppant blender [9]

4. MIXING THE PROPPANT DIRECTLY WITH CARBON DIOXIDE

This technology is still not popular among gas production companies. It allows minimalizing the ignition risk of gel based on methyl alcohol and simplifying the whole

process. This method includes the injecting proppant material into a non-aqueous fracturing fluid stream. The first system, without using indirect fluid, was proposed by Bullen and Lillies. Figure 6 shows a scheme of this system. In the first step, fracturing is carried out without the proppant. Grains of proppant are put into the fracture from container after the fracture is formed. Cooled proppant is transported under pressure by a screw mechanism to the tube wherein liquid CO_2 flows and lifts grains together. The vessel is hermetically closed in order to achieve proper pressure modification [10].

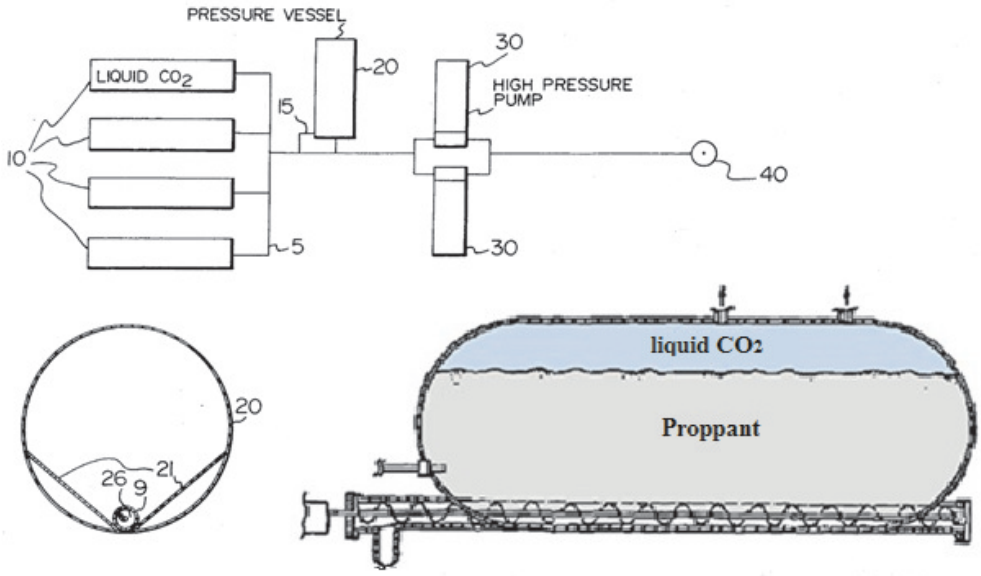

Fig. 6. Scheme of mixing system by Bullen and Lillies [10]

5. CONCLUSIONS

Low viscosity of CO_2 complicates carrying the proppant, thus it is a challenge to find appropriate fracturing fluid and a method of mixing. Imprecise fracturing equipment is a reason of restricting the application of liquid CO_2 fracturing. Nowadays, gas production companies apply their own methods for blending and dosing proppant into the wellbore. Many of these methods have been borrowed from the hydraulic fracturing. Some of them have been modified. The ways of mixing proppant can be divided into methods requiring indirect fluid to join proppant with liquid carbon dioxide and methods applying direct mixing. The known gels are almost always based on alcohol and are therefore highly flammable, therefore, handling and pumping pose serious fire hazards. Moreover, mixing proppant with these gels is carried out at atmospheric pressure, thereby it increases a fire risk by the release of potentially explosive vapors into the surrounding atmosphere. The fact is that without proppant fracturing would not be economically viable.

REFERENCES

[1] www.infolupki.pgi.gov.pl (access 23.02.2016).

[2] Mazza R.: *Liquid-Free Stimulations – CO_2/Sand Dry-Frac*. Conference Proceedings of Natural Gas 1997.

[3] Lianga F., Sayeda M., Al-Muntasheria A., Changb F., Lia L.: *A comprehensive review on proppant technologies.* Petroleum 2016.

[4] Mack M., Sun J., Khadilkar C.: *Quantifying Proppant Transport in Thin Fluids – Theory and Experiments*. The SPE Hydraulic Fracturing Technology Conference, Woodlands, TX, 2014.

[5] Mack G., Coker C.E.: *Proppant Selection for Shale Reservoirs: Optimizing Conductivity, Proppant Transport and Cost.* SPE Unconventional Resources Conference Canada.

[6] *Economical, efficient, effective. Using carbon dioxide for well fracturing*: Praxair brochure 03/2013.

[7] Grassman D., Zingg W.: *Well fracturing method using liquefied gas as fracturing fluid*. Patent US 3842910 A.

[8] *Fracturing Fluid Systems. Broad Variety of Systems Enables Customizing the Treatment Fluid to Reservoir Requirement*. Halliburton brochure 07/2013.

[9] www.tricanwellservice.com (access 28.02.2016).

[10] Bullen R., Lillies A.: *Carbon dioxide fracturing process and apparatus*. Patent US 4374545 A.