Effect of Temperature on the Transport Properties of Hydraulic Fracturing Fluid through Fractured Sandstone

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Abstract: In this study, the effect of temperature on the transport of fracturing fluid through a sandstone up to a pressure of 700 psi (splitting tensile strength of rock) was investigated. The fracturing fluid used in this study had 90% water, 9% fine sand and 1% guar gum. The permeability of the rock almost doubled from 1.37 to 2.7 mD when the temperature was increased from 25°C to 85°C at a pumping pressure of 700 psi.

1. Introduction

Hydraulic fracturing is a technique used to free oil and natural gas trapped underground in low permeability rock formations by injecting a fluid under high pressure in order to crack the formations. In the United States shale gas and oil production has grown rapidly in the past years to continuous technological developments in hydraulic fracturing. Fracturing hydraulically rocks and shale allows an increase in permeability by opening, connecting and keeping open pre-existing or new fractures in the formation. The design of the fracturing fluid is therefore critical to the success of the treatment. Fracturing fluids main function is to not only open the fracture the rock but also to keep it open. The fracturing fluid must exhibit other important properties such as less fluid loss and low friction of pressure during pumping (API RP39 1998). The composition of a fracturing fluid varies with the nature of the formation, but typically contains mostly (99%) water and proppant sand to keep the fractures open and a small percentage of chemical additives (Murrill and Vann 2012).

2. Objectives

The overall objective was to evaluate the changes in the permeability of sandstone when the fracturing fluid flows at increased temperature and pressure (close to the splitting tensile strength of rock).

3. Methods and Materials

To study the effect of temperature on the permeability of the rock, the saturated rock samples were pre-cracked by performing the splitting tensile strength test. Double ring steel mold 2.3″ in diameter * 7″ height was used in this study. Annular space between the rock and the wall of the mold was sealed using a polymer grout. The mold provided two valves stem, one of the valve to collect side volume leakage and the other valve to collect the water coming from the rock sample. The fracturing fluid on the top of the rock sample was subjected to various pressures up to 700 psi. The hydro-fracturing test study was performed at two different temperature 25°C and 85°C. For each environmental condition the discharge and permeability of the rock sample was measured with time.

4. Results and Analysis

Total of 102 data were collected from the literature on the density of rocks which varied from 2.18 to 2.88 gm/cm^3 as shown in Fig.1. The density of unsaturated rock used in this study was 2.45 gm/cm^3. Total of 21 data on compressive strength (σ_c) and permeability for different type of rocks were collected from the literature. Based on the literature data, the correlation between compressive strength (σ_c) and permeability was developed. Unconfined compression tests and constant head permeability test were conducted on the 2.3" D *3.3" H sandstone rock sample according to ASTM standard. The compressive strength and permeability of the sample used was 9000 psi and 6*10^{-10} mD respectively as shown in Fig. 3. Increasing applied pressure on the fracturing fluid from 100 psi to 700 psi increased the permeability by 96% at room temperature as shown in Fig.4; also with increasing the temperature from 25^{o}C to 85^{o}C the permeability with the fluid increased by 70% under a pressure of 700 psi as shown in Fig.4.

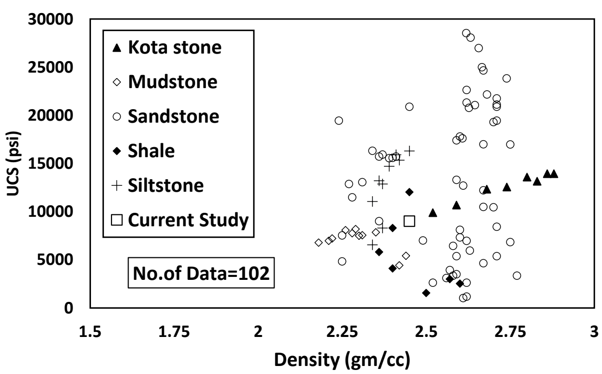

Figure 1. Variation of Density and Compressive Strength of the Rocks

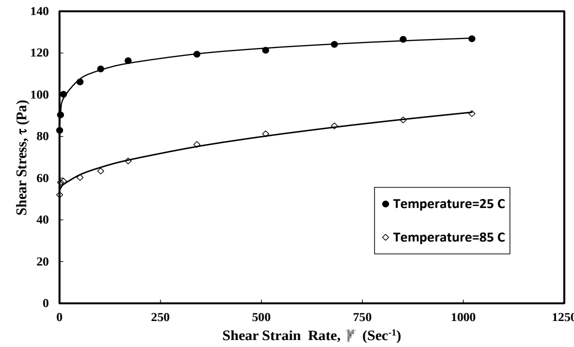

Figure 2. Relationship between Shear Stress- Shear Strain Rate of Fracturing Fluid

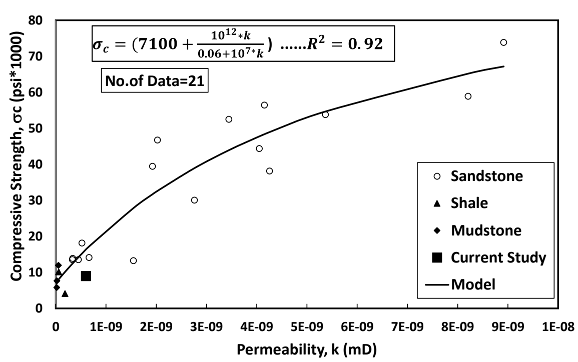

Figure 3. Relationship between Permeability and Compressive Strength of the Rocks

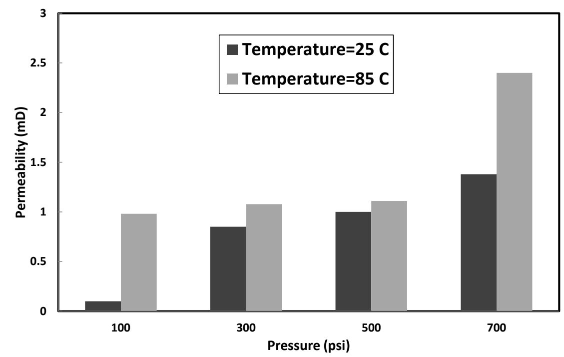

Figure 4. Changes in Permeability of Fractured in Sandstone under Pressure and Temperature

5. Conclusions

Based on this study, the permeability of the sandstone rock increased with increase in the pressure and temperature of the rock for the fracturing fluid used in this study.

6. Acknowledgements

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7. References

1. API RP39. (1998)" Recommended Particles on Measuring the Viscous Properties of Cross – linked Water based Fracturing Fluid."

2. Murrill, B. and Vann, A. (2012). "Hydraulic Fracturing: Chemical Disclosure Requirements" Congressional Research Service, R42461, pp. 1–23.

3. Vipulanandan C., Mohammed, A. and Qu, Q. (2014). "Characterizing the Hydraulic Fracturing Fluid Modified with Nano Silica Proppant" AADE-14-FTCE-39, pp. 1-12.