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Review article

Application of polymers for coating of proppant in hydraulic fracturing of subterraneous formations: A comprehensive review

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ABSTRACT

Polymers have extensively been employed by petroleum industry to maintain, treat and optimize drilling and production operation in oil and gas wells. Polymers minimize solid deposition in wells, maintain fluid viscosity, thicken water, reduce downtime caused by corrosion and maintenance work, but can also be used to clean well and surface equipment. One of the most widely forms of polymer application in oil and gas industry is related to coating of proppant in hydraulic fracturing (HF) operation. Proppants are small spheres that must have enough strength to withstand to high closure stresses. Application of polymers for coating of proppants is just emerging in recent years and promises higher performance by taking the both of strength and flexibility context into account. Coating of proppant with a thin layer of polymer will results in higher fracture conductivity, considerably reduce fines generation and scaling, thereby improving the quality of HF treatment. This paper reviews the polymer application for coating of proppants in HF treatment. The purpose of this article is three-fold: (1) to update petroleum and chemical scientists and engineers on the latest development in polymer utilization for coating of proppant, (2) to give some basic details on proppants and polymers to help understand why these developments came about and to (3) summarize the latest advances in proppant coating methods and procedures.

1. Introduction

Hydraulic fracturing (HF) is known as the main and effective method for increasing oil and gas recovery (Zoveidavianpoor et al., 2010) and since its inception; it has made significant contributions to the petroleum industry (Veatch and Moschovidis, 1986). The 1970s have seen the resurgence of HF treatment. Much of the resurgence has been due to the decline of the US domestic gas production that turns the interest in improving ways to extract oil and gas from unconventional formations.

Various combinations of fracturing fluids and proppants can be designed based on individual well conditions and as can be seen from Fig. 1, proppant is the second abundant constitute with ~9.5 weight percent. As discussed by Holditch (1979), the ideal propping agent has a low density, resistant to crushing and corrosion, is strong and readily available at low cost. Proppant as a derivative of the combination of synthetic based or natural based materials is used to keep open the fracture. Proppant Market report categorizes the global market by three types; sand, ceramic, and Resin Coated Proppant (RCP) that are utilized by 80%, 10% and 10% by volume (see Fig. 1). In general, the availability of the newly created fracture area is limited for production, if no proppants are placed in the fracture to keep it open. The function and the representative compound of the additives used in fracturing fluid are tabulated in Table 1.

The importance of HF technology explains why production of unconventional gas reservoirs (i.e., very tight porous formations) which are economically challenging, have proved satisfactory. The substantial portion of the gas production from shale plays has made the United States as the largest natural gas producer in the word, which achieved via the introduction of HF technology (Wang et al., 2014). The boom in the development of proppant coating is being fueled by continued improvements in proppant technologies for fractured wells.

Coated proppant has created many benefits for the upstream petroleum industry. Therefore, the present study addresses the most common types of polymers for coating of proppant, advantages and disadvantages of polymer coatings, and their performance in different conditions. Also, this paper provides an overview of common methods for coating of proppant. The present

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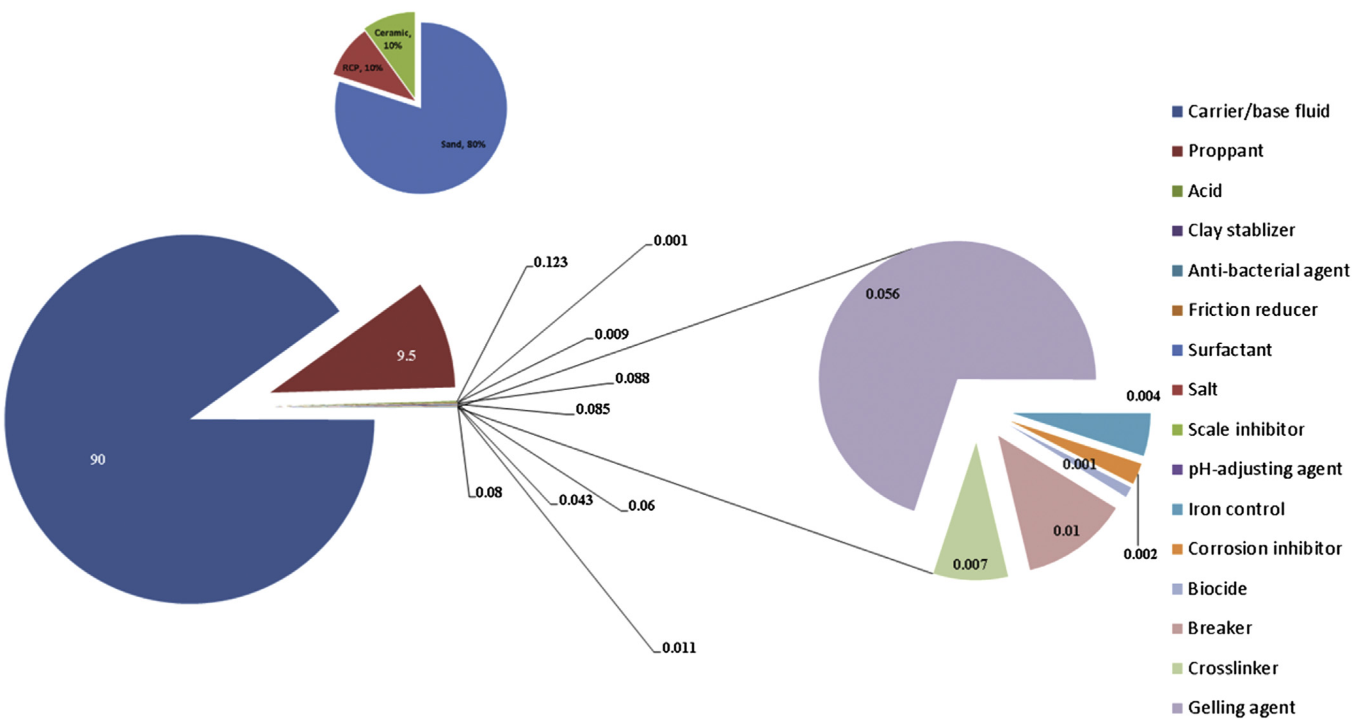

Fig. 1. Composition of a typical fracturing fluid (modified from Arthur et al., 2008).

study offers an opportunity for researchers to know more about various types of proppant and their properties, advantages of using polymers for coating of proppant, and processes and procedure of coating proppant.

2. Proppant

Proppants are small particles used in combination with fracturing fluid to keep the created fracture open during HF treatment. Proppant can be classified in two categories; conventional and advanced. Conventional proppants include sand, ceramic, nutshells, and glass beads. Proppants that are coated with a thin layer of polymer are known as advanced proppants. Comprehensive information about different types of proppants and their properties is presented in Table 2. According to the Proppant Market Report (PMR, 2014), the proppant market in 2013 exceeded 45 million tons, a 28% increase compare to 2012 and predicted to reach 84.2 million tons by 2019 at a compound annual growth rate of 10.7% from 2014 to 2019. More than 99% of that supply is met with sand, resin-coated sands, and ceramic proppant.

3. Low-weight proppant evolution

The relatively low cost, abundance, sphericity, and low specific gravity of high-quality sands have made sand a good proppant for most HF treatments. However, the closure stress on the substrates increases with depth and fracture conductivity has been found to deteriorate rapidly when closure stresses exceed approximately 6000 psi. In response to this problem and to resist the increased closure stress of deeper wells, several higher-strength proppants have been developed including sintered bauxite (Cooke, 1977), ceramic (Sarda, 1981) and resin-coated sand (Sinclair and Graham,

Table 1
Typical composition of HF fluid.

Constituent	Representative compound	Purpose
Carrier/base fluid	Fresh water	Fracture the rock
Proppant	Sand	Holds fractures open after flowback
Acid	Hydrochloric or muriatic acid	Dissolves minerals and initiates cracks in the rock
Clay stabilizer	Choline chloride	Prevents formation clays from swelling
Anti-bacterial agent	Glutaraldehyde	Eliminates bacteria
Friction reducer	Polyacrylamide	Minimizes friction between the fluid and the pipe
Surfactant	Isopropanol	Increases the viscosity of the fracture fluid
Salt	Potassium chloride	Creates a brine carrier fluid
Scale inhibitor	Ethylene glycol	Prevents scale deposits in pipes
pH-adjusting agent	Sodium or potassium carbonate	Maintains effectiveness of chemical additives
Iron control	Citric acid	Prevents precipitation of metal oxides
Corrosion inhibitor	n,n-dimethyl formamide	Prevents pipe corrosion
Biocide	Glutaraldehyde	Minimizes growth of bacteria that produce corrosive and toxic by-products
Breaker	Ammonium persulphate	Allows a delayed breakdown of gel polymer chains
Crosslinker	Borate salt	Maintains fluid viscosity as temperature increases
Gelling agent	Guar gum or hydroxyethyl cellulose	Thickens water to suspend the sand