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Review

Smart magnetic markers use in hydraulic fracturing

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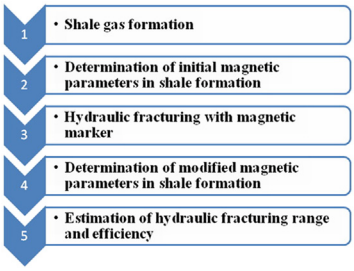
HIGHLIGHTS

- Obtaining maximal range of fracturing is crucial for fracturing efficiency.
- Smart magnetic marker may allow fracturing range assessment.
- A potential magnetic marker has to have strong magnetic properties.
- A marker has to meets other criteria: physical, chemical, ecological and economical.
- The best potential magnetic marker may be ferrite.

GRAPHICAL ABSTRACT



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ABSTRACT

One of the main challenges and unknowns during shale gas exploration is to assess the range and efficiency of hydraulic fracturing. It is also essential to assess the distribution of proppant, which keeps the fracture pathways open. Solving these problems may considerably increase the efficiency of the shale gas extraction. Because of that, the idea of smart magnetic marker, which can be detected when added to fracturing fluid, has been considered for a long time. This study provides overview of the possibilities of magnetic marker application for shale gas extraction. The imaging methods using electromagnetic markers, are considered or developed in two directions. The first possibility is the markers' electromagnetic activity throughout the whole volume of the fracturing fluid. Thus, it can be assumed that the whole fracturing fluid is the marker. Among these type of hydraulic fracturing solutions, ferrofluid could be considered. The second possibility is marker, which is just one of many components of the fracturing fluid. In this case feedstock magnetic materials, ferrites and nanomaterials could be considered. Magnetic properties of magnetite could be too low and ferrofluids' or nanomaterials' price is unacceptably high. Because of that, ferrites, especially ZnMn ferrites seems to be the best material for magnetic marker. Because of the numerous applications in electronics, it is cheap and easily available, although the price is higher, then that of magnetite. The disadvantage of using ferrite, could be too small mechanical strength. It creates an essential need for combining magnetic marker with proppant into magnetic-ceramic composite.

Contents

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1. Introduction

1.1. Shale gas exploitation

Shale gas has been increasingly become important source of natural gas in the United States for the last two decades. Rich resources of this gas are found in Canada, Europe, China, Algeria and the United States (de Guire, 2014). Among European countries, Poland is a pioneer in shale gas exploration and exploitation (Zawadzki and Bogacki, 2016a). Extraction can be carried out by drilling techniques coupled with hydraulic fracturing. Hydraulic fracturing (fracking) is a method of inducing fracturing of shale. During fracking, water, proppant (sand or other ceramics) and some chemicals are pumped in high pressure into the well. As a result of fracturing, large amount of very small cracks (fractures) are made in shale. Proppant enters the interior of produced fractures and prevents the fractures from closing (Liang et al., 2015). The use of the proppant is shown in Fig. 1. If fractures are fully open, natural gas can migrate from shale, through a well, into a receiver (gas tank or pipeline).

1.2. Economic and environmental aspects of fracturing

During single hydraulic fracturing over hundred thousand cubic meters of water, over thousand tons of proppant and over thousand cubic meters of chemical addictives could be used (Konieczyńska et al., 2011). Many of compounds used are highly toxic (US HoR CoEaC, 2011). Shale gas exploitation may cause habitat and landscape fragmentation, extraction sites can be equated to heavy industrial zones (Baranzelli et al., 2015) in terms of pressure on the environment (US EPA, 2011; Meng, 2015). For this reason, numerous attempts are increasingly made, to develop methods for the shale gas extraction, alternative for the use of hydraulic fracturing and water-based fluid (Gandossi, 2013; Rogala et al., 2013).

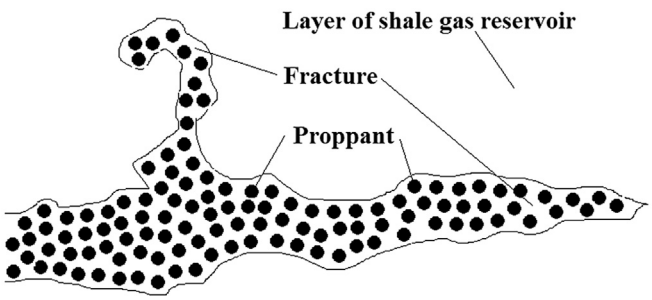

Fig. 1. Scheme of proppant arrangement in the fracture.

Proper fracturing, proper selection of the fracturing fluid composition, the proppant amount and quality are crucial to the overall project's economic viability and, as a result, the amount of shale gas obtained (Yuan et al., 2015). From the economic point of view, it is crucial to obtain maximal range of fracturing (Bicerano, 2010). Another very important thing is to assess the range and efficiency of hydraulic fracturing.

1.3. Hydraulic fracturing range assessment

There are numerous geological underworld mapping and data analysis methods, such as: seismic analysis, electromagnetic methods, magnetotelluric methods (Weymer et al., 2015), nuclear magnetic resonance and magnetic resonance imaging (Chen et al., 2013; Xiao and Li, 2011). All of those methods are complicated and hard to apply at reservoirs' depth. Because of that, the idea of smart marker, added to fracturing fluid, has been developed. A lot of markers have been used, for example radionuclides (Attendorn and Bowen, 1997; Ferronato et al., 2004). But radionuclides should not be used in hydraulic fracturing, because of contamination (environmental pollution) risk.

Because of massive use, a marker has to be environmentally friendly - non toxic and rather non reactive. It also has to be cheap. Those criteria can be met by smart magnetic marker – a substance, which is active in magnetic (natural or inducted) field (Cocuzza et al., 2012). The range of hydraulic fracturing can be assessed by measurement of vertical and horizontal component of earth's magnetic field before and after fracturing. The difference should be caused by magnetic marker particles (Byerlee and Johnston, 1976; Meyer, 2015). The use of the proppant with magnetic marker is shown in Fig. 2. The aim of this study is to determine the conditions and possibilities for selection of potential magnetic material, used as magnetic marker in shale gas hydraulic fracturing.

2. Materials' magnetic properties

One of the most important parameter defining the magnetic material properties is a volume magnetic susceptibility, χ_V, the parameter which describes how material can be magnetized in external magnetic field (Hunt et al., 1995) (Eq. (1)):