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Research Article

Application status and research progress of shale reservoirs acid treatment technology

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Abstract

In recent years, shale oil and gas development has been thriving in China. However, the shale oil and gas production always suffers a rapid decline. Based on the analysis of a large amount of former theories and experiences, a summary of acid treatment stimulation methods in shale oil and gas is presented, and the acid stimulation mechanism is analyzed. The mainstream technique in acid treatments includes: acid wash, matrix acidizing, prop fracturing with acid preflush, and multi-stage alternate-inject acid fracturing. The main stimulation mechanism of acid treatment can be summarized into 3 categories: a) the influence on shale matrix, namely the acid-induced increase of porosity and permeability, and reduce of wetting property of shale; b) the influence on rock mechanical properties, namely shale brittleness and toughness, and even Young Modulus to some degree; c) the influence on fractures' conductivity, caused by the fact that acid dissolves calcite-enrichment area in priority, and then increases roughness on fracture surface. In room temperature and atmospheric pressure, acid reduces fractures' conductivity, while in pressurized condition, the acid-soaked fractures' conductivity is higher than the conductivity of non-acid-soaked fractures. These knowledges would provide useful reference for furthering stimulation techniques and processes in shale oil and gas development.

Keywords: Shale reservoirs; Acid treatment technology; Stimulation; Stimulation mechanism; Research status

With the ever increasing demand for energy and depleting conventional reservoirs, the oil and gas industry is more and more dependent on the commercial development, and prolonging production from unconventional shale counts. The exploitation of shale oil and gas resources has great benefits from the progress of horizontal drilling techniques combining with hydraulic fracturing. Slick water is the most commonly used fracturing fluid, which may be adopted to achieve maximum contacted reservoir surface area, known as stimulated reservoir volume (SRV) [1].

However, there are still many challenges in the process of production, the most important challenge is that many of the wells suffer drastic decline in production over the initial one year period [2]. The reason is due to a) the proppants are in uneven distribution. The complex fracture network is created by slick water. In medium, there are many microfractures whose width is mainly between 10^{-6} cm and 10^{-1} cm. Because they are too small to be accessed by most common proppants, such as 40–70 or 100 mesh sand, and the proppant carrying ability of slick water is low (maximum is 2 lbs/bbls), therefore, when reservoir pressure declines as oil and gas produced from the formation, the declining pore pressure leads to increase of effective closure stress. As a result, microfractures are not able to support the increasing effective closure stress mounts. This condition limits the producible reservoir volume to the primary fracture, leading to a steep decline in production [3–10]; b) proppant fatigue due to stress cycling and digenesis [11]. Therefore, we need find a way to keep these unpropped fractures and microfractures open. Acid fracturing, as an alternative technology for hydraulic propped

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fracturing, can be a potential solution to improve the productivity of microfractures in carbonate-rich shale.

It is widely believed that acid treatment technology is basically invalid in shale oil and gas stimulation, because: a) although shale contains some acid soluble minerals, such as calcite and dolomite, their distribution is very uneven in shale, which induces difficulties in creating successive channels with conductivity after acid dissolve these minerals; b) the mineral composition of shale is of great variety, thus the effect of acid stimulation becomes difficult to estimate. Therefore, to alter stereotypes for only use of hydraulic fracturing in shale oil and gas stimulation, this paper introduces the application of acid treatment technology in shale oil and gas stimulation and discusses its stimulation mechanism in detail. It can be concluded that, acid treatment technology has a great application prospect and provides a new stimulation idea for shale oil and gas reservoir stimulation.

1. Application status of acid treatment technology in shale oil and gas reservoir

1.1. Downhole acidic scale removal and matrix acidizing

Acid was initially used to stimulate shale oil and gas well for the purpose of removing precipitated carbonate and of well stimulation. Honolulu Oil Corp., operator for the Antelope Shale Zone Unit, Buena Vista Hills, initiated an acid treatment program, Oct. 23, 1956. 35 wells were treated with acid, and yielded a net increase oil of 1390B/D and gas increase of 3265 Mcf/D [12].

Except for downhole acidic scale removal, matrix acidizing is also an effective stimulation method. In matrix acidizing, acid is injected into the near-wellbore reservoir, and then it removes the blockage in the near-wellbore reservoir, such as precipitated carbonate and mud pollution, and dissolves some carbonate rock which is packed in natural fracture, and etches the fracture face. Correspondingly, the near-wellbore reservoir conductivity is recovered or even increased, and oil and gas production increase. There are many successful cases of matrix acidizing in shale oil and gas reservoir [13–16]. One area of successful matrix acidizing was in the Monterey N/NA shale at Elk Hills, Nabil EL Shaari [13] believed that the success is due to a) improving the wellbore connection into naturally-fractured calcareous intervals, and b) the impact of reducing skin across a thick production interval.

1.2. Pad-acid-hydraulic fracturing technology

In S.E. Oklahoma Woodford shale frac job, injection of thin frac treating fluid into shale results in high pumping pressure and low injection rate, so volumes of various types of acid systems are pumped with surprising results [17]. The job plot is shown in Fig. 1. Likewise, J. Fontaine [18] introduced that Marcellus shale gas frac job have similar procedure. Pad acid not only can obviously reduce initiation fracture pressure, but also can remove the pollution in near wellbore. Therefore, this hydraulic fracturing method with pad acid is widely applied in shale oil and gas stimulation [19–23].

1.3. Multistage alternating injection proppant-carrying acid fracturing

Acid treatment technology is not just limited to acidic scale removal, matrix acidizing and pad-acid-hydraulic fracturing. Currently, multistage alternating injection proppant-carrying acid fracturing technology has obtained successful application, which combines the advantages of acid fracturing with hydraulic fracturing, not only can remove the near wellbore pollution, improve the microfracture conductivity, but also can release more adsorbed gas.

In one reported case, two of six Caney shale wells were treated in McIntosh County, Oklahoma using acid. Verbal reports indicated a two-fold higher initial production (IP) in the treated vs. untreated wells. In another case in Coal County, Oklahoma, two Woodford shale wells treated with acid were reported to flow up casing for a two-week period in an area not normally capable of flowing without assist. Table 1 illustrates a Woodford shale pump schedule incorporating the use of 3% HCl. Up to 280,000 gallons of 3% acid, or 30% by volume of total fluid pumped, have been placed in a Caney shale well [17].

Williams Production Co. experimented with acid in the Caney shale [8]. Initial production from their first attempt was exceptional compared to previously completed wells. The stimulation effect in the well lasted past 200 days.

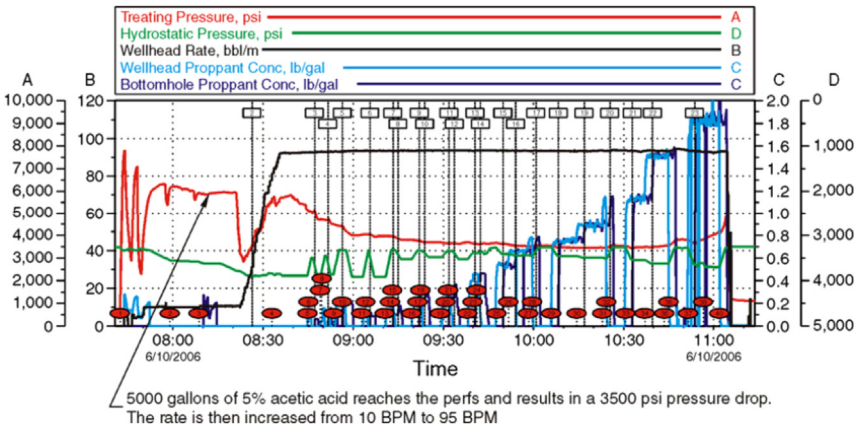

Fig. 1. Job plot from S.E. Oklahoma Woodford shale frac job showing dramatic/unexpected pressure drop as reactive fluid hits the perfs.