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Research Article

Research and field tests of staged fracturing technology for casing deformation sections in horizontal shale gas wells☆

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Abstract

Horizontal shale gas well fracturing is mostly carried out by pumping bridge plugs. In the case of casing deformation, the bridge plug can not be pumped down to the designated position, so the hole sections below the deformation could not be stimulated according to the design program. About 30% of horizontal shale gas wells in the Changning and Weiyuan Blocks, Sichuan Basin, suffer various casing deformation after fracturing. Previously, the hole sections which could not be stimulated due to casing deformation were generally abandoned. As a result, the resources controlled by shale gas wells weren't exploited effectively and the fracturing effect was impacted greatly. There are a lot of difficulties in investigating casing deformation, such as complex mechanisms, various influencing factors and unpredictable deformation time. Therefore, it is especially important to seek a staged fracturing technology suitable for the casing deformation sections. In this paper, the staged fracturing technology with sand plugs inside fractures and the staged fracturing technology with temporary plugging balls were tested in casing deformation wells. The staged fracturing technology with sand plugs inside fractures was carried out in the mode of single-stage perforation and single-stage fracturing. The staged fracturing technology with temporary plugging balls was conducted in the mode of single perforation, continuous fracturing and staged ball dropping. Then, two kinds of technologies were compared in terms of their advantages and disadvantages. Finally, they were tested on site. According to the pressure response, the pressure monitoring of the adjacent wells and the microseismic monitoring in the process of actual fracturing, both technologies are effective in the stimulation of the casing deformation sections, realizing well control reserves efficiently and guaranteeing fracturing effects.

Keywords: Shale gas; Horizontal well; Casing deformation; Staged fracturing; Staged fracturing with sand plug; Staged fracturing with temporary plugging ball; Field test; Sichuan Basin; Changning and Weiyuan Blocks

0. Introduction

In China, shale gas is endowed extensively, with huge development potential [1]. Shale reservoirs are characterized by poor physical properties, low porosity and ultra-low permeability, so they can produce shale gas industrially only after fracturing stimulation [2–4]. Globally, horizontal well staged fracturing is mainly adopted. In order to improve the stimulation effect to expand the stimulated reservoir volume (SRV) and form complex fracture networks in shale reservoirs, staged fracturing technology with large liquid volume, large displacement and cluster perforation is usually used. Generally, for a single horizontal shale gas well, the fluid volume in hole ranges from 3×10^4 to 4×10^4 m^3 during fracturing, and the displacement is 10–14 m^3/min. In view of this, staged fracturing technology with cluster perforation and cable-

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conveyed bridge plug is selected. If a casing deformation occurs during the fracturing operation, the bridge plug cannot be pumped to the designed position, so the hole sections below the deformation section can not be stimulated, and the reserves of such hole sections can not be effectively produced, extremely leading to an unsatisfactory fracturing performance. In this paper, the staged fracturing technology with sand plugs inside fractures and the staged fracturing technology with temporary plugging balls were tested in casing deformation wells. The staged fracturing technology with sand plugs inside fractures was adopted in the mode of single-stage perforation and single-stage fracturing. The staged fracturing technology with temporary plugging balls was applied in the mode of single perforation, continuous fracturing and staged ball dropping. Both technologies were successful in field tests, thus providing reference for the fracturing of similar wells.

1. Casing deformation during horizontal shale gas well fracturing

In the Changning and Weiyuan Blocks, Sichuan Basin, about 30% of horizontal shale gas wells suffered various casing deformations during or after fracturing in the Longmaxi shale gas reservoir. Fig. 1 shows the logging results with the multi-arm caliper when a well suffered casing deformation during fracturing. This well was completed using the Ø127 mm casing with steel grade Q125 and wall thickness of 12.14 mm, and revealed serious casing deformation according to the well logging results.

According to the statistical analysis of casing deformation wells, the probability of casing deformation is high in areas with faults and natural fractures. Large-scale fracturing changes the in-situ stress field around the well and thus destroys the original in-situ stress balance, resulting in the existence of lithologic interface, heterogeneous strata, and sliding of strata with bedding, which may be the main cause for casing deformation. Moreover, wellbore trajectory, cementing quality, and temperature effect may also be sensitive factors for casing deformation [5–13]. The casing deformation in large-scale hydraulic fracturing operation is complicated in mechanism and affected by several factors, and its timing is difficult to predict. Therefore, it is very important to find an effective stimulation treatment for horizontal shale gas wells with casing deformation in the study area.

2. Staged fracturing in casing deformation sections

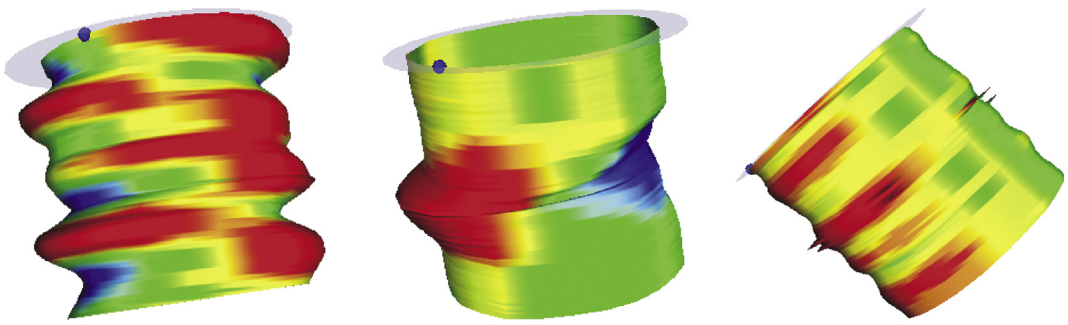
Once casing deformation occurs, the original bridge plug will impossibly pass through the deformation section. Given small casing deformation, the bridge plug with a small OD within its setting range can be selected based on the ID of casing to continue the horizontal well fracturing. In most cases, however, it is difficult to find a suitable staged fracturing tool, and the hydraulic jetting fracturing tool is not qualified for downhole conditions, once a casing deformation exists. It is necessary to figure out a new staged fracturing process.

2.1. Staged fracturing with sand plugs inside fractures

When the fracturing of the target interval is completed, proppant with high sand concentration or large grain size is injected to form plugging inside fractures. The fracturing fluid or sand-carrying fluid injected subsequently can hardly enter into the plugging section, but turn to a new unstimulated section. In this way, staged fracturing is realized.

In general, sand plugs occur in fractures or wellbores during fracturing due to the effect of displacement and liquid performance; besides, sand plugs may form in fractures if the width of fractures induced by fracturing does not match the concentration and grain size of proppant. The study reveals that the average fracture width must be slightly larger than the average grain diameter in the case of low proppant concentration, and the average fracture width must be 3 times that of the average grain diameter in the case of high proppant concentration, so that the sand-carrying fluid can flow into the fractures. The sand plugs are mainly generated by injecting proppant with large grain size or high sand concentration. The latter is usually applied on site in consideration of the limited types of proppant.

Ideally, sand plugs should be formed after the proppant is completely injected into the formation. Otherwise, if the proppant is not completely injected into the formation, overpressure will occur to lead to pump stopping, finally resulting in sand settling in the wellbore. In field application, short



a. Max. ID 105.70 mm; Min. ID 102.58 mm
Avg. ID 104.13 mm

b. Max. ID 105.24 mm; Min. ID 103.03 mm
Avg. ID 104.21 mm

c. Max. ID 105.02 mm; Min. ID 102.75 mm
Avg. ID 103.67 mm

Fig. 1. Logging results with the multi-arm caliper when a well suffered casing deformation during fracturing.

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