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A new coal particles cleanout technology in coalbed methane wells in China

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ABSTRACT

Coal particles regularly flow into coalbed methane (CBM) wells with the formation water. Once they settle down in the bottom of CBM wells, the pump will get stuck and the reservoir will be buried. In conventional oilwells, sand cleanout is usually operated by circulating the cleaning fluid into the wellbore to bring sand particles to the surface. However, when applied in CBM wells, this traditional hydraulic particles hoisting technology would leak the working fluid into the formation, destroy the coalbed formation structure and jam the formed channel of gas because the bottomhole pressure (BHP) is low.

In this paper, a continuous vacuum cleanout technology will be introduced, and it combines a novel jet pump with a concentric tubing string (CTS) to remove coal particles without placing hydrostatic loads on the reservoir. The novel jet pump has two nozzles and the CTS is assembled by the outer tubing and inner tubing. More specifically, a high pressure working fluid is pumped through the CTS annulus from the surface and then it is divided into two parts. One part of the fluid acts as the sand carrier fluid. The other part acts as the power fluid of the jet pump to create a localized drawdown which vacuums the carrier fluid together with coal particles into the jet pump, and then circulates coal particles to surface through the inner tubing.

The detailed structure and the principle of the technology system are described, while a theoretical model is built to design and optimize the system which is based on the coal particles transport experiment data and the jet pump theory. The field applications have proved that the coal particles cleanout technology makes significant improvements in achieving high efficiency and preventing leakage in CBM wells, and more importantly, reduces the skin damage and improves the CBM production.

1. Introduction

In the eastern margin of the Ordos Basin of China, the CBM wells belong to the low reservoir pressure and absorption wells. The BHP of CBM wells is very low, usually ranges from 1 to 5 MPa, and the coal reservoir fracture characteristics are highly developed (Xinfu, 2013). In principle, coal particles are dragged by the formation fluids, which are water and gas, carried out through the formation fractures and settle down at the bottom of the well. By the time the casing is full of the sedimentary solids, the production zone becomes plugged and the downhole pump gets stuck. Workover activities have to be carried out to bring the well back into production (Song et al., 2010). Frequently, removal of wellbore fill is considered inadequate, leaving large quantities of coal particles in the well, which often requires repeating well cleanouts in a relatively short time interval. On average, the period between two cleanout operations is 5 months for CBM wells. In addition, wellbore cleanouts are extremely time consuming and costly, preventing timely return of wells to production and increasing the cost of well maintenance (Rolovic et al., 2004).

The main purpose of conventional solids cleanout operation is to circulate the solid particles out of the wellbore with the power fluid, which is injected into the wellbore to lift particles and carry them out to the surface. However, such fluid circulation puts excess hydraulic pressure on the formation, which does not suit to CBM wells because of the low BHP, resulting in lost circulation into reservoirs. Besides, incomplete removal of the coal particles occurs due to the fact that a certain amount of solids may be forced back into the formation. Then, when the well is revived for production, these solids move back into the wellbore and settle down at the bottom of the well. This is similar to a kind of sanding in conventional oilwells. In CBM wells, a large amount of working fluid would leak into the formation. In this case, it is not only difficult for the well to return to normal production after being put back into operation, but also introduces serious damage to the formation near the wellbore (Li et al., 2010).

Foam or energized fluids are usually used for solids cleanout in low pressure and/or absorption wells. The carrying capacity and

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suspension properties of these fluids are superior but they were hindered by other geometric influences on the velocity profile (Engel and Rae, 2002). Solids entrainment and re-entrainment into the fluid, as would be expected, is difficult to achieve without mechanical assistance (Ozbayoglu et al., 2005). Therefore, they are more operationally complicated and may cause negative effects if not properly handled by the field operations and engineering personnel (Li et al., 2005).

At present, sand bailers are used to remove coal particles in CBM wells. Two common types of bailers are the vacuuming type, i.e. the Venturi junk basket (Haughton and Connell, 2006) and the mechanical type, i.e. "screw" rotational sand bailer (Hansen, 2004). The materials, typically cleaned in this method, include falling metal objects, milling material, large "rocks", cement, and consolidated material. These are not likely to be circulated out with the above mentioned cleanout methods. Sometimes, the sand bailer is used to identify the top of fill and evaluate the conditions where other sand cleanout process would be applicable (Santhana Kumar et al., 2005). However, the method is poorly efficient because the coal particles can easily float in fluid and handling sand bailers frequently is extremely time-consuming.

As is mentioned above, it is more difficult to achieve high efficiency of coal particles cleanout in CBM wells due to a large amount of fluid leaking into the formation.

In this paper, a new coal particles cleanout technology is developed for achieving higher efficiency of coal particles cleanout in CBM wells by employing the CTS and a modified jet pump. It can avoid excess hydraulic pressure on the formation, because the fluid is circulated in the CTS without contact of the casing. The jet pump generates the Venturi effect, and sucks the coal particles carrier fluid. The main advantage of this novel technology is to remove coal particles efficiently and protect the formation. The structure and the principle of the technology system are described firstly. Secondly, experiments have been performed to study the coal particles transport properties in the carrier fluid. Thirdly, a theoretical model is formulated to determine and optimize the operation parameters on the basis of the experimental coal particles transport behavior and the jet pump theory. Finally, a field case is presented to demonstrate the design and application of the novel coal particles cleanout technology.

2. Structure and principle

According to the working area, the coal particles cleanout technology system is divided into two subsystems: the surface subsystem and the downhole subsystem.

The surface subsystem consists of a plunger pump, a separation tank, a gas recovery facility, and flow meters etc., as shown in Fig. 1. The downhole subsystem is composed of the Concentric Tubing String (CTS), the modified jet pump with a flow diverter and a down nozzle, etc. as shown in Fig. 2.

In principle, the working fluid, i.e., water, is boosted by the plunger pump on the surface, injected into the downhole jet pump through the annulus of the CTS, and then divided into two parts by the flow diverter, as shown in Fig. 2. The jet pump nozzles are used to convert the high pressure head of the working fluid into the high velocity head. One part of the working fluid flows through the down nozzle to impact the coal particles, form the coal particles carrier fluid. The high velocity of the carrier fluid will accelerate to stir up the coal particles at the bottom of the wellbore and carry them upwards to the throat of the jet pump via the suction chamber. The other part of the working fluid flows through the up nozzle of the pump, generates high velocity and lowers the pressure at the bottomhole to suck the carrier fluid together with the coal particles into the pump. Then, the above mentioned fluid–solid stream and the power fluid are mixed in the throat of the jet pump and enhanced pressure in the diffuser, thus,

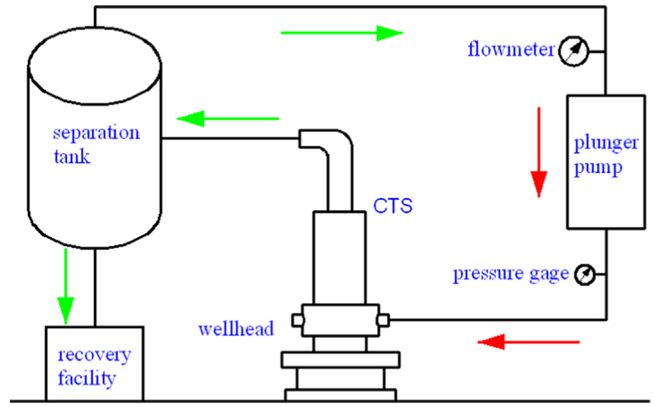

Fig. 1. Schematic of the surface subsystem.

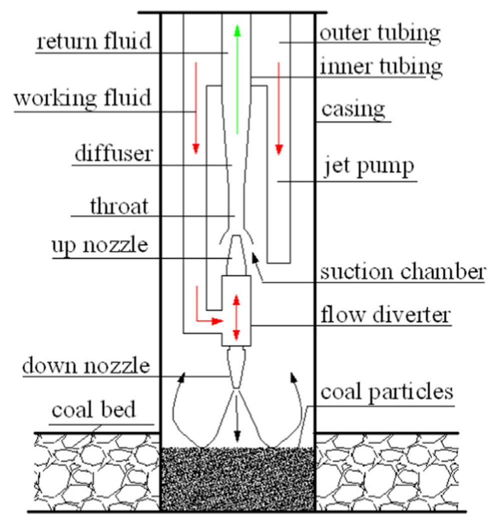

Fig. 2. Schematic of the downhole subsystem.

lifted upwards to the surface via the inner tubing string. Return fluids are routed to a gas/water/solids separation tank. Any gas returns are routed to the recovery facility. The fluids in the separation tank are filtered and to be recirculated to the fluid pumps.

3. Coal particles transport properties

Solids transport in cleanout processes is a very complex problem, to make the coal particles cleanout operation work, coal particles at the bottomhole of the wellbore need to be activated and lifted upwards with the carrier fluids. Thus, it is necessary to understand the coal particles transport properties in the carrier fluids. Previously, numerous efforts have been made to study the behavior of solid transportation and wellbore cleanouts with various fluids (Tomren et al., 1986; Sifferman and Becker, 1992; Walker and Li, 2000; Li and Wilde, 2005). Generally, it is found that there exists a critical velocity of the fluids below which the solids form a bed at the bottom of the wellbore. In a vertical well, It is common rule of thumb that the critical velocity should be twice as much as the coal particles settling velocity to ensure the coal particles are lifted upwards to the surface with the carrier fluid when water is used as the carrier fluid (Walton, 1995).

To make a better understanding of the correlations between the carrier fluid velocity and the coal particles settling velocity, experiments are performed in this study to determine the required critical velocity of the carrier fluid that is sufficient for carrying the coal particles out of the well.