INTELLIGENT PUMPING DOWN PERFORATING AND PLUG METHOD FOR UPWARD SHALE GAS WELL

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AUTHORS: Dengbo Yang, Qingbin Zhang, Kai Tang, Guohui Ren, Xindi Zhao,
China Nation Petroleum Corporation
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November, 2009, 1st pumping down operation in China, Smith Company, in EOG Sichuan Tight Gas Project

July, 2010, 1st shale gas well of China perforated, vertical, CNPC

2013, China become the 3rd country in the world realizing profitable exploitation of shale gas

In 2017, China reaches an annual shale gas production of 9.027 billion cubic meters (0.319 tcf)

Most shale gas fields in mountainous region of Sichuan basin in southwest China.
No special method taken, string slipping back, wireline damaged, or burst into the gap between gun string and casing
F_P has nothing to do with P_1
It depends entirely on the gap structure and fluid parameters

Pumping Force: \[ F_P = P_1 \cdot A_1 + P_2 \cdot A_2 + P_3 \cdot A_3 + P_4 \cdot A_4 - P_5 \cdot A_5 \]
THEORETICAL ANALYSIS

The tangential component of the combined force of gravity and buoyancy

Friction between pipe string and casing

Cable head tension

\[ F_r + F_{f1} + F_c \geq (G - F_F) \cdot \cos \alpha + f_1 \cdot (G - F_F) \cdot \sin \alpha + f_2 \cdot (G_c - F_{Fc}) \]

Relation of pushing pump rate and pushing force in normal condition (5.5 “ Casing)

Relation of pushing pump rate and pushing force during plug setting (5.5 “ Casing)
Calculation of pushing pumping rate

E.g. well inclination is 105°, pushing force needed is 224N~1545N, According to the calculation, pushing pumping rate is 0.48~0.9 m³/min.
To keep from slipping, pushing rate should be kept as long as possible during the process of setting plug.

As the bridge plug expands, pushing force increases sharply, causing damage to the cable head.

To ensure safety, it is necessary to stop pumping when the plug expands to a certain outside diameter.
- Set pump overpressure to control and stop pumping automatically.
- Stop pumping when cable tension increase.
(1) Down hole cable tension:  
- Collect cable head tension real time,  
- Transfer to intelligent pumping down system

(2) Intelligent pumping down system:  
- Auto load parameters, calculate and remind of down hole situation,  
- insure safety of upward well pumping down.

Automatically loading perforating data, selecting designated casing collar and providing voice prompts, significantly increase efficiency

Automatically calculating tool string velocity, assessing tool status with down hole tension data, increase or decrease pump rate accordingly.
(3) Network interconnection platform:

- To share operation information real time
- Perforating expert remote online guidance
- Data analysis and operation optimization
APPLICATION

- Vertical depth difference between the starting point of horizontal section and toe of well is 131m
- Plug depth at 3469m (110.5°)
- Tool string weight of 420 kg

APPLICATION

1. Remain 0.6 m³/min pumping rate while setting plug, auto stop when pressure increase 1 MPa
2. Keep 0.48 m³/min rate while perforating, no slipping, no complex situation

Totally been applied in over 200 upward shale gas wells
A calculation model of pushing force was established. The recommended pumping rate of upward wells can be calculated. On-site applications show that the recommended pumping rate can ensure safety.

Remain pumping rate while setting plug, set auto stop function of pump when pressure increase 1~2MPa, insure cable head safety.

Using cable head tension and intelligent pumping down system to increase efficiency, using network platform to get remote guidance in complex operation and analyze data to optimize operation.
QUESTIONS? THANK YOU

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