

The Causes and Prevention Measures of Stuck Pump Phenomenon of Rod-pumped Well in CBM Field

Mei Yonggui

Petrochina Huabei Oilfield CBM Branch Company, Jincheng, Shanxi Province, China

E-mail:meiyonggui@126.com

Abstract: In the process of CBM field exploitation, in order to realize the drainage equipment to work continuous stably, the article pays attention to study and solve the stuck pump problem, and aim of reducing reservoir damage and lowering production costs. Through coal particles stuck pump experiment and sediment composition analysis, we find out five primary cause of stuck pump phenomenon: sand from coal seam, sediment from ground, iron corrosion, iron scrap caused by eccentric wear, coal cake. According to stuck pump mechanism, the article puts forward 8 measures to prevent stuck pump phenomenon, and the measures are focused on technology optimization, operation management and drainage process control. After 7 years production practice, the yearly stuck pump rate has dropped from 8.9% to 1.2%, and the pump inspection period has prolonged 2 times. The experiment result shows that pure coal particles cannot cause stuck pump, but sand, scrap iron, and iron corrosion are the primary cause of stuck pump. The article study and design the new pipe string structure that the bottom of the pipe string is open. This kind of pipe string applied the sedimentation terminal velocity theory to solve the stuck pump phenomenon, and it can be widely used in CBM drainage development.

1 Foreword

In the exploitation of the Chinese CBM field, beam pump unit with tubing pump is adopted as a primary drainage method, and the proportion of rod-pumped wells in CBM wells has reached 96.1%. In the CBM production process, due to the failure of the stuck pump as the main reason for the pump inspection, the pump inspection period of most CBM development companies was only more than 300 days. Many experts and scholars hold different views on the reason of CBM wells stuck pump phenomenon. Huo Xuan and Liu Shenggui considered coal powder as the main cause of stuck pump phenomenon^[1-2], and they started to study the warning system of coal powder concentration. Aiming at the problem of the stuck pump, He Guowei and Yao Jin proposed the sand control pump with long plunger^[3-4]. Wang Shuisheng thought iron scrap caused by eccentric wear was one of the reasons, and suggested installing rotary magnetic protector to rod string^[5]. Zhu Jing investigated the adaptability of the tubing pump, and considered the critical working conditions of pump, sand from layer, corrosive formation water and lubricative liquid obstruct the normal working of the pump^[6].

Cai Hua applied the OPRS software to simulate the location of eccentric wear on the rod string .so as to achieve the optimal design of centralizers^[7]. Xu Yaobo analyzed the causes of the eccentric wear, developed anti-eccentric wear tools and optimized the structure of sucker rod centralizer^[8-9]. Ren Lichang and Jia De attempted to prevent the eccentric wear phenomenon via optimizing the rod and tubing string, adjusting the pumping parameter and applying rotary centralizer^[10-11]. Li Xiuzhu introduced sucker rod centralizers of different types to prevent eccentric wear^[12]. Their work contributed a lot to preventing the eccentric wear phenomenon and prolonging pump inspection



period.

Qi Yaoguang designed coal powder reverse circulation washing device of hydraulic jet pump [13]. Shen Zhonghua studied the relationship of the speed of falling particles and the water velocity [14]. Guan Feng simulated the calculation model of the sedimentation terminal velocity in a vertical well [15]. They all studied the sedimentation terminal velocity of solid particles.

The author sorted and analyzed the production data of more than 2600 rod-pumped CBM wells, studied the reason of the stuck pump phenomenon through experimental methods, and arrived at a conclusion that the coal powder was not the cause of the stuck pump. This article puts forward 8 effective measures to prevent stuck pump phenomenon from 3 aspects, and these measures have been proved in the long-term CBM production practice.

2 Cause analysis of stuck pump

This article consider that the coal powder is not the cause of the stuck pump phenomenon, because the micro structure of coal is that tiny and fragile coal chips joined together. In order to prove this viewpoint and find out the exact cause of the stuck pump phenomenon, the author has done experiment to simulate the actual working condition of the tubing pump, and analyzed the composition of sediment. The experiment has two purposes, one is to verify the possibility of the coal particle causing stuck pump, and the other is to analyze the composition of the sediment, and understand its source.

2.1 Verification experiment of possibility of coal particle causing stuck pump

1) location: 11-4 well;

2) Principles of selecting well:

- ① Water production: 3-15m³/d. The water quality is clear;
- ② Gas production: less than 200m³/d, little effect on production during stopping well.
- ③ No stuck pump occurred during the past production process.

3) Preparation of the experiment

① Take a piece of coal, and grind it into powder and particles. Separate the coal powder and particle for two parts:

One part the diameter of the coal particles is less than 1.2mm (include the powder), the amount is 1000ml;

Another part the diameter of the coal particles is less than 3mm (include the powder), the amount is 1000ml;

② Experimental tools

Prepare 48" and 24" pipe wrench each for one, a screwdriver with a long arm, a 1500 ml measuring cup, a 10000 ml bucket, a 300 mm*150 mm plastic board and labor protection appliance.

③ On December 31st, 2010, make the horse head stop at the top dead center and the bottom dead center separately, and stop the beam pumping unit for 2 hours, then start the pumping unit to prove that the stuck pump phenomenon don't happen in the test well under normal circumstances.

4) Process of experiment

To prove that the coal powder is not the cause of the stuck pump phenomenon, experiment was carried out from January 21st to 23rd, 2011.

Experiment 1:

① Stop the pumping unit at the top dead center, dismantle the packing box and take out the packing, then block the outlet of the wellhead waterline with the plastic plate.

② Mix the coal particles which is less than 1.2mm (include the powder) with water, stir well and add it into the oil tube with measuring cup.

③ Install the packing and the packing box, start the pumping unit after 8 hours, pumping properly. Then test the bottom dead center again, the pump worked properly.

Experiment 2:

① Stop the pumping unit at the top dead center, dismantle the packing box and take out the packing, then block the outlet of the wellhead waterline with the plastic plate.

② Mix the coal particles which is less than 3mm (include the powder) with water, stir well and add it into the oil tube with measuring cup.

③ Install the packing and the packing box, start the pumping unit after 24 hours, pumping properly. Then test the bottom dead center again, the pump worked properly.

5) Experimental data and summary

The experimental data are shown in table.1.

Table.1 Data table of the coal particle stuck pump experiment

Experiment	Amount of the coal /ml	Diameter of the particle /mm	Time of halting the pumping unit /h	Result
Experiment 1	1000	<1.2	8	None stuck pump
Experiment 2	1500	<3.0	24	None stuck pump

Experimental conclusion: Through two experiment with different halting time and different amount and diameter of the coal particle (include coal powder), the test results proved that the pure coal particle or powder will not cause the stuck pump.

2.2 Sediment composition analysis

In order to analyze the sediment composition, the author collected the solid particles from the wellbore, the pump cylinder, the plunger and valve of the well which was inspected because of the stuck pump phenomenon(Fig.1、 Fig.2).

1) Composition of the sediment from wellbore

The proportion of the solid particles ($d > 0.12\text{mm}$) is 40%. Most of the particles are asphalt, stone scrap and quartz sand. The asphalt ($1.26\text{mm} < d < 10\text{mm}$) accounted for 45%. The stone scraps ($2\text{mm} < d < 5\text{mm}$) accounted for 40%. The rest are quartz sand ($0.2\text{mm} < d < 1.2\text{mm}$).

The proportion of the solid particles ($d < 0.12\text{mm}$) is 60%. Most of the particles are coal powder, iron, clay and quartz sand.



Fig.1 Sample of well-hole sediment

2) Composition of sediment from pump cylinder

The pump cylinder sediment consist of asphalt, saturated hydrocarbon, aromatic hydrocarbon, coal powder, iron, clay, quartz sand and other solid particles, and they are mixed as thick coal cake which has a certain hardness. The proportion of asphalt, saturated hydrocarbon, aromatic hydrocarbon is 55%, and that of the rest solid is 45%.



Fig.2 Sample of pump cylinder sediment

2.3 Summary of the causes of the stuck pump phenomenon

Through two experiments with different halting times and different amounts and diameters of coal particles (including coal powder), it was proved that coal particles (including coal powder) were not the cause of the stuck pump phenomenon. Through analysis of the sediment that caused the stuck pump phenomenon, it is certain that sand, iron scrap, and coal cake are the dominant causes.

3 Source analysis of causing stuck pump matter

Through analysis of the sediment that caused the stuck pump phenomenon, the author found that the sediment is from five origins.

1) Sediment from ground

In the process of well inspections, if field operators lack safety consciousness and operating skills when inspecting or measuring the sucker rod and tube, sediment and stone scrap from the ground might adhere to the sucker rod and tube (especially on rainy days). As a result, sediment from the ground that adhered to the rod and tube was taken into the wellbore. It might drop into the space between the plunger and the valve when the pumping unit was started. Then the stuck pump phenomenon appeared.

2) Sand from coal seam

Hydraulic fracturing with active water and quartz sand is widely used in the development of CBM wells (including vertical wells and directional wells). The fracturing quartz sand varies into fine sand, medium sand, and coarse sand by diameter. The diameter of fine sand is 0.212mm-0.425mm, while the diameter of medium sand is 0.425mm-0.85mm, and that of coarse sand is 0.85mm-1.2mm.

It is a common phenomenon that sand comes out from the coal seam after fracturing. But the severity varies. When the inlet of the pump is below the coal seam, the fracturing sand can flow into the pump cylinder with the seam water easily. If the water speed is high, the sand particles flow up with water through the tube, and when the water speed is lowered for some reason, the sand particles in the tubing might drop down to the space of the pump cylinder and plunger. Then the pump might get stuck.

3) Rust

CBM wells use N80 type iron as tube and D type iron as sucker rod. The iron might corrode while storing on the outdoor ground. The use of old tubing is even more serious, and may cause 1mm-2mm rust. If the rust of the sucker rod and tube were not cleared up in time during pump inspections, the rust might fall off, drop into the drainage pump, and cause the stuck pump phenomenon.

4) Iron filings caused by eccentric wear

When the pumping unit is working, the sucker rod moves up and down in the wellbore. Eccentric wear happens to the sucker rod and tube in this process because of the nature angle of the well, the severe overall angle change rate, neutral point influence, casing deflection deformation, and other factors (Fig.3). Iron filings may appear because the horse head of the pumping unit is not precisely fixed to the well hole, which results in eccentric wear between the sucker rod and the packing box in some CBM wells, then the stuck pump happens. Collecting the impurities in the pump cylinder, a large number of adsorptions can be confirmed as iron filings by magnet.



Fig.3 Sucker rod joint with eccentric wear and stuck pump caused by iron filings

5) Coal cake

During pump inspection, thread compound (alternate named thread dope) should be doped to the threaded connections. If the operations staff uses too much thread compound, the superfluous thread compound might drop down to the surface of the plunger and the pump. Besides, solid particles like coal powders would mix with the thread compound, then the coal cake formed. As time went on, the coal cake became harder like dumpling wrappers, and it is one of the causes of the stuck pump phenomenon.

4 Anti stuck pumping measures

The article puts forward 8 measures to prevent stuck pump phenomenon, and the measures are focused on technology optimization, operation management and drainage process control.

4.1 Technology optimization

1) Tubing string structure optimization

① Calculations applied the sedimentation terminal velocity theory

Stokes formula:

$$v_1 = gd^2(\rho_1 - \rho_2) / 18\mu \quad (1)$$

In this equation, v_1 represents speed of the solid particles, m/s;

d represents diameter of the particles, m;

ρ_1 、 ρ_2 respectively represent the density of the particles and water, kg/m^3 ;

g represents gravitational acceleration, m/s^2 ;

μ represents viscosity of water, $\text{Pa}\cdot\text{s}$.

Equation to calculate the water velocity in tubing:

$$v_2 = q / (s_1 - s_2) \quad (2)$$

In this equation, v_2 represents speed of water in tubing, m/s;

q represents water rate of the CBM well, m^3/d ;

s_1 represents the sectional area of the tubing inner diameter, m^2 ;

s_2 represents cross sectional area of the sucker rod, m^2 ;

The density of the fracturing sand (quartz sand from Lanzhou) is $2.65 \times 10^3 \text{ kg/m}^3$. The density of 20°C water is $0.998 \times 10^3 \text{ kg/m}^3$, and the viscosity is $0.001 \text{ Pa}\cdot\text{s}$. The density of the coal in Qinshui Basin is 1500 kg/m^3 . The inner diameter of the tubing is 0.0062 m , and the diameter of the sucker rod is 0.0019 m .

After calculation applied equation 1, and equation 2, we get the speed data of particles of different diameter in different water production wells. The data is in the Table.2.

Table. 2 Data of sand particles sedimentation velocity with different diameter in different water production

Diameter of sand(mm)	Sedimentation velocity of sand(m/s)	Speed of water in tubing(m/s)	Daily water production(m^3/d)
0.05	2.25×10^{-3}	2.96×10^{-3}	0.7

0.07	4.41×10^{-3}	6.35×10^{-3}	1.5
0.1	8.99×10^{-3}	1.27×10^{-2}	3
0.12	1.30×10^{-2}	1.69×10^{-2}	4
0.15	2.03×10^{-2}	2.54×10^{-2}	6
0.2	3.60×10^{-2}	4.44×10^{-2}	10.5
0.25	5.62×10^{-2}	6.77×10^{-2}	16
0.3	8.09×10^{-2}	9.74×10^{-2}	23
0.35	1.10×10^{-1}	1.33×10^{-1}	31.5
0.4	1.44×10^{-1}	1.74×10^{-1}	41
0.425	1.62×10^{-1}	1.95×10^{-1}	46
0.85	6.50×10^{-1}	7.83×10^{-1}	185

The amount of daily water production decreases with the production time goes on in CBM wells. The initial water production is mainly around 10 m^3 - 15 m^3 , and less than 4 m^3 , even without liquid during the stable production period.

From the data of the Table 2, it's known that sand particles ($0.2 \text{ mm} < d < 0.25 \text{ mm}$) can be brought up to the ground at the initial stage of production. In the stable stage of production, the solid particles ($d < 0.12 \text{ mm}$) can be brought up.

② The open tail tube design

According to sedimentation terminal velocity theory, the author designed new pipe string structures for vertical and directional wells. Install a tail tube (ordinary oil tube) at the bottom of the pipe string, and remove the screen tube and the pipe plug structure, to ensure the bottom of the pipe string is open.

The flowing area below the pump is larger than that above the pump because of the sucker rod. Therefore, the water speed below the pump in tubing is higher than that above the pump. If the solid particles can be brought up from the tail tube to the pump, it could obviously be brought up to the ground because of the higher water speed in tubing above the pump (fig.4).

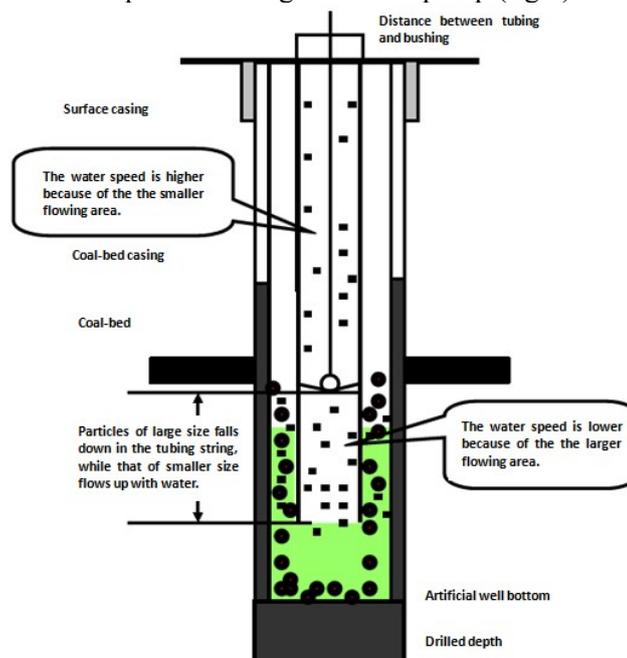


Fig.4 The flow velocity in pipe string sketch

2) Application of the centering sucker rod

In order to relieve the influences of the eccentric wear, the centering sucker rod which injected 3 centralizers on each sucker rod, is applied in all the rod strings of the vertical wells and directional wells.

4.2 Strengthen the operating management

1) Ensure the cleaning of rod and tubing

Strengthen the operators protecting conscious, and make sure to clean up the sand from ground adhered on the rod and tube. Avoid taking ground sand into the wellbore through the sucker rod and oil tube.

2) Rust removing

Operators should clean up the rust on the sucker rod and the tubing, especially the used tubing with longer stored time. Before the tubing is run into the wellbore, operators must have the steel beat with a hammer for several times to clear the rust, and use the tubing gauge pass through the tubing string to avoid the adverse effect on the pump.

3) Apply proper amount of thread compound

Dope with moderate thread compound to threaded connections of the sucker rod and the oil tube. Do not dope with too much thread compound, and clean up the superfluous thread compound to avoid the formation of coal cake.

4.3 Drainage process control

1) Reasonable control of stroke frequency

In the steady stage of the CBM well production, daily water production of more than 90.6% wells is less than 4 m³. Therefore, to change a smaller pump to improve the pump efficiency, or adjust the pumping stroke frequency to reduce the eccentric wear and formation of iron filings seems a good choice.

2) Start the pumping unit at a low speed

In the initial stages of CBM well production, as the seam water pressure is high, if the parameter of the pumping unit is too high, quartz sand of large diameter might brought up into the tubing string with seam water. But when the daily water production decreases, water speed in the tubing string becomes slow, and the quartz sand may drop down to the tubing string and stuck the pump. To avoid the phenomenon, it is advised that the stroke speed of new wells, or wells which have been just inspected, be adjusted at a low level (probably at 0.9 min⁻¹, depending on the state). As the water becomes clean, adjust the pumping stroke speed gradually according to the decrease of the bottom hole flowing pressure until fulfilling the needs.

3) Low liquid wells intermittent pumping

The daily water productions of more than 70% CBM wells is less than 0.7 m³. It is advised that running system of this kind of wells be interval. Applying this interval running system will reduce the running time of the pumping unit, relieve the eccentric wear, and prolong the pump inspection period on the premise of not influencing the gas production.

5 Effectiveness evaluation

During the time from 2013 to 2017, all the screen tubes and pipe plugs have been removed, and the open design of tail tube is widely used in more than 2100 CBM wells of the Branch Company. Pump inspection caused by the stuck pump decreased from 164 times in 2013 to 32 times in 2017 (fig.5). The ratio of stuck pump inspections decreased from 8.9% to 1.2% (fig.6). The average pump inspection period prolonged from 583 days to 1102 days (fig.7)

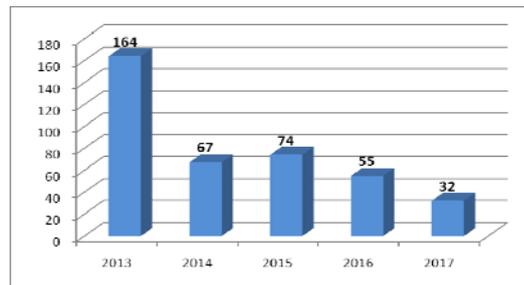


Fig.5 The frequency of pump inspection caused by stuck pump among 2013-2017

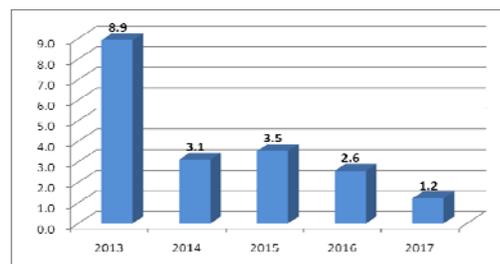


Fig.6 The proportion of stuck pump phenomenon among 2013-2017

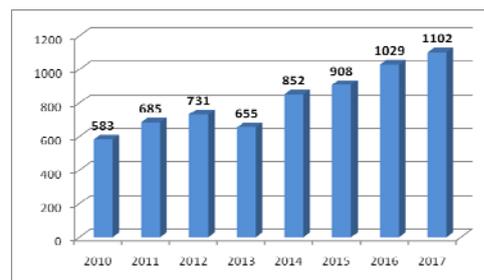


Fig.7 The statics of average pump inspection period among 2010-2017

6 Conclusion and advice

1) Pure coal powder or particles will not cause the stuck pump phenomenon of the tubing pump.

2) Ground sediment, fracturing sand, rust, iron filings and the coal cake are the true causes of the stuck pump phenomenon.

3) Strengthening the operating management, optimizing pipe string structure and controlling reasonable drainage parameters can greatly reduce the proportion of the stuck pump.

The paper puts forward 8 measures to avoid the stuck pump phenomenon, and the measures have been proved effective. It is advised that the measures be widespread applied in the CBM field.

The iron filings generated by eccentric wear, which is a primary cause of the stuck pump, still exists. Further research should be carried out to prevent eccentric wear.

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