

# Analysis of Downhole Throttling Technology of Gas Wells

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## ABSTRACT

Downhole throttling technology relies on downhole throttling to achieve the purpose of wellbore throttling and pressure reduction. Compared with surface throttling, downhole throttling can not only use ground temperature heating, effectively prevent the shaft and wellhead from freezing, but also reduce the wellhead pressure and save the cost of surface pipeline. It solves many technical problems in the process of gas well production, and plays a key role in energy saving and safety production of gas well. At present, a set of mature calculation methods have been developed for the production calculation of conventional gas Wells. However, for throttle gas Wells, due to the influence of fluid accumulation, the accuracy of conventional calculation method is low, which leads to a large error in the selection of throttle size. Therefore, it is of great practical significance to study the downhole throttling technology and optimize the parameters of downhole throttling.

## KEYWORDS

Gas Wells; Downhole Throttling; Air Tap.

## 1. INTRODUCTION

The downhole throttling process of gas wells can use the appropriate position of the lower throttle in the wellbore to achieve depressurization and cooling, and the throttle can effectively prevent the formation of hydrates in the wellbore because the formation temperature exceeds the critical temperature of hydrate formation, which can effectively prevent the formation of hydrates in the wellbore and simplify a series of gas recovery processes such as surface throttling and heat preservation. The downhole throttle nozzle is similar to the cross-sectional retraction device, and the natural gas will increase the flow rate and reduce the pressure after passing through the throttle nozzle, such as reducing the natural gas temperature by throttling, so that it exceeds the critical temperature of the natural gas forming hydrate under the pressure condition, and can be used to achieve throttling and cooling, so as to achieve the effect of avoiding the formation of hydrate.

## 2. RESEARCH BACKGROUND AND SIGNIFICANCE

China is one of the first countries to use natural gas in the world, and the consumption of natural gas ranks first in the world. With the development of the industrial revolution and the continuous progress of science and technology, due to the late start of the development of China's oil and gas field, less experience, and the development of oil and gas industry is difficult, the technical level in this field has been far behind the developed countries. However, with the development of Daqing oil field, Changqing Oil field, Tarim oil field and other large oil and gas fields, China has gradually lost the "hat" of backward countries in oil and gas industry. Statistics show that from 2010 to 2050, the world's energy demand will increase by 60% [1]. Natural gas will also surpass coal and oil and become the

largest energy consumption, providing new opportunities for the development of China's natural gas field.

With the increasing demand for natural gas and the continuous development of new and old gas fields, all kinds of problems will follow. China's gas field exploration and development is difficult, and there are many high-pressure gas Wells, due to the underground pressure is too large, the gas flow rises to the wellhead will still maintain a high pressure, transportation pipeline to bear too much load, not only high risk, but also increase the gathering and transportation cost. In addition, under the action of high pressure and low temperature, natural gas hydrate is easy to produce in the upper part of the wellbore and wellhead, resulting in freezing and blocking of the wellbore and wellhead, which increases the difficulty of exploitation. Downhole throttling technology can solve the problem of high pressure gas well exploitation. Compared to installing a surface choke at the wellhead, there are several advantages to running a choke downhole [2]. First, the downhole choke can reduce the wellhead pressure, prevent the wellhead fluid pressure is too high, the flow rate is too fast, and the surface line is worn out. Secondly, the downhole temperature is high, and after the throttle reduces the temperature of the fluid, the geothermal gradient can be used to heat up the fluid quickly, destroy the hydrate generation environment, and effectively prevent wellbore freezing. Finally, there is no need to install heating devices on the ground, which significantly reduces mining costs and energy consumption. At present, downhole throttling technology has been widely used in Sulige gas field and Shenmu gas field in China. However, there is still a lack of research on the running boundary conditions, the factors affecting the throttling effect and the reasonable running depth of the throttling, and it needs to be strengthened. Therefore, the research on the optimization of throttling process parameters in deep Wells is of great significance to improve the field work efficiency.

### **3. SUMMARY OF DOWNHOLE THROTTLING TECHNOLOGY PRINCIPLE**

Downhole throttling technology refers to the use of downhole throttling to achieve wellbore throttling and pressure reduction. Then, through the heating effect of ground temperature, the fluid after throttling is heated, so that the wellhead fluid temperature is basically equal to the temperature before throttling. It can effectively avoid the formation of hydrates in the wellbore, thereby preventing the gas-water mixture from freezing the wellbore or wellhead. It is an effective solution to solve many difficult problems in wellbore and surface during gas well production to install suitable downhole throttles. At present, there are widely several problems in the use of downhole throttles, including poor throttling effect, high failure rate, difficult fishing, short effective period, etc. The main reasons include the following six points [3]:

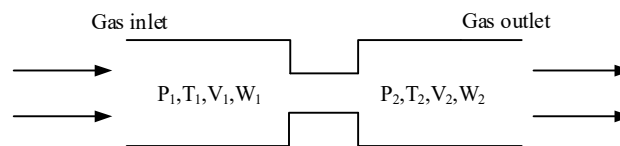
- (1) the sealing surface of downhole throttles is too small, the slips are too long, and the wellbore Angle has too much influence on the throttles, which is easy to reduce the sealing effect.
- (2) In the process of fishing the failed throttle, due to the high hardness of the sealant cylinder, it is difficult to reset in a high temperature environment. During the lifting process, the friction between the rubber cylinder and the inner wall of the tubing is large, which leads to the serious sticking phenomenon.
- (3) In the process of fishing the failed throttle, due to the poor sealing effect of the throttle seat, some throttle seat seals fall seriously. Like a throttle falling to the bottom of a well.
- (4) In the process of fishing the failed throttle, due to the sand production of the gas well, the socket cannot grasp the throttle or it is difficult to unseal the throttle normally.
- (5) In some gas Wells, after the downhole throttle is put in, the effect of the throttle is poor or does not work.
- (6) The frequency of switching Wells is too high, resulting in the failure of downhole choke.

## 4. RESEARCH ON DOWNHOLE THROTTLING MECHANISM

Downhole throttling technology reduces wellbore pressure, and the fluid is insulated by the formation after throttling, so that the temperature of the fluid under low pressure rises, which is higher than the hydrate formation temperature under the pressure condition, effectively preventing the formation of hydrate in the well and reducing the amount of methanol injection. Due to the small size of the gas nozzle and the large volume flow of the mixture, the flow rate of the mixed flow through the gas nozzle is extremely high, which can effectively improve the liquid carrying capacity of the gas well. For the surface, downhole throttling technology can reduce the pressure of the surface pipeline, reduce the safety threat of the surface personnel and equipment, and simplify the surface engineering facilities. In order to solve the problems existing in the production of high water cut gas Wells by using downhole throttling, it is necessary to study the mechanism of downhole throttling, so as to realize the efficient development of downhole throttling technology.

### 4.1. Critical Flow Conditions for Fluid Throttling

In gas well production, when the natural gas passes through the throttle, the volume flow of the mixture is large, but the size of the gas nozzle is small, and the gas volume expands at the lower part of the gas nozzle, so the gas velocity may increase to the sound velocity and reach the critical flow state, and the flow condition to reach the critical flow state is similar to that of the oil well nozzle flow. The throttling process can be regarded as a process of fluid sudden contraction and expansion. The fluid flows in the pipe section and flows through the throttling air nozzle, the flow area of the fluid becomes smaller, the fluid is compressed, and the flow rate increases [4]. The fluid flow rate is related to the pressure ratio and the aperture size of the upper and lower ends of the throttle nozzle. When the speed of the fluid flowing through the throttle is close to the speed of sound, the pressure on the lower end of the nozzle will not be affected by the change of the upper end pressure. When the fluid passes through the throttle nozzle, its own pressure, temperature, and volume change, as shown in Fig.1.



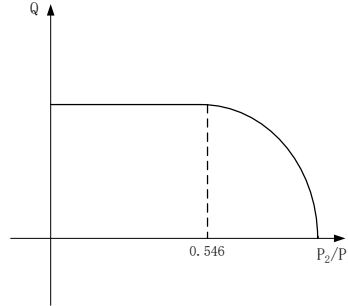
**Fig.1** Schematic diagram of gas flow through throttle

There are two flow states when the fluid passes through the throttle nozzle, they are critical flow state and subcritical flow state. In the production of natural gas Wells under downhole throttling conditions, the critical pressure ratio of natural gas flowing through the throttling gas nozzle is:

$$\beta = \frac{P_2}{P_1} = 0.546 \quad (1)$$

As shown in Fig 2, there is a correlation between the output of a natural gas well and the throttle pressure ratio. When the pressure ratio is less than 0.546, it is a critical flow, that is, the pressure wave generated by the throttle effect will not be transmitted after the throttle, and the gas well can produce steadily. Moreover, when the fluid is in a critical flow when it passes through the gas nozzle, the flow rate behind the gas nozzle is only related to the diameter of the throttle. However, when the flow is

greater than 0.546, it is a subcritical flow, and the pressure wave generated before throttling will spread to the wellhead through the throttle, causing wellhead pressure fluctuation, resulting in unstable gas well production. Therefore, most studies at home and abroad consider the throttling prediction model under the critical flow state.



**Fig.2** Schematic diagram of relationship between throttling flow and pressure ratio

#### 4.2. Calculation of Throttle Pressure Drop of Gas Flowing through Fixed Nozzle and Determination of Nozzle Diameter

As shown in Fig 2, when the gas passes through the throttling nozzle, a large pressure drop will be generated. When the ratio of the pressure after throttling (downstream pressure  $P_2$ ) to the pressure before throttling (upstream pressure  $P_1$ ) reaches 0.546, that is, the critical flow state is reached. At this time, any pressure wave will not be transmitted through the throttling nozzle to the throttling nozzle (downstream outlet to the throttling nozzle), and the output will not change. According to the flow law of natural gas flowing through the throttle nozzle, in the non-critical flow state, the relationship between the pressure before and after throttling and its flow is as follows:

$$Q_{sc} = \frac{0.408 P_1 d^2}{\sqrt{\gamma_g T_1 Z_1}} \sqrt{\frac{k}{k-1} \left[ \left( \frac{P_2}{P_1} \right)^{\frac{2}{k}} - \left( \frac{P_2}{P_1} \right)^{\frac{k+1}{k}} \right]} \quad (2)$$

Where  $Q_{sc}$  is the volume flow through the oil nozzle (under standard condition),  $104\text{m}^3/\text{d}$ ;  $P_1$  and  $P_2$  are respectively the pressure before and after the nozzle, MPa;  $d$  is the nozzle diameter, mm;  $T_1$  is the temperature before the nozzle, K;  $Z_1$  is the gas deviation coefficient under  $T_1$  and  $P_1$  conditions.  $\gamma_g$  is the relative density of gas, calculated as  $\gamma_g = 0.56$ ;  $k$  is the adiabatic index, and 1.3 is calculated for natural gas.  $P_2/P_1$  is the pressure ratio. For critical flow, calculate the critical pressure ratio  $(P_2/P_1)_c$  according to equation (2), and the maximum atmospheric flow rate is:

$$Q_{\max} = \frac{0.408 P_1 d^2}{\sqrt{\gamma_x T_1 Z_1}} \sqrt{\frac{k}{k-1} \left[ \left( \frac{2}{k+1} \right)^{\frac{2}{k-1}} - \left( \frac{2}{k+1} \right)^{\frac{k+1}{k-1}} \right]} \quad (3)$$

The reasonable throttle nozzle diameter of gas well is determined mainly according to the reasonable output of gas well, the pressure drop before throttling and the upstream temperature before throttling. When the gas flows through the fixed nozzle and reaches the critical flow state, the output will not change. At this time, the output of the gas well is only related to the diameter of the throttle nozzle. Therefore, the diameter of the throttle nozzle can be reasonably determined through the gas well production allocation. Combined with  $k=1.3$ , the reasonable throttle nozzle diameter is obtained by the transformation:

$$d = \sqrt{\frac{Q_{sc}}{0.849P_1^4} \sqrt{\frac{\gamma_g T_1 Z_1}{\left(\frac{P_2}{P_1}\right)^{1.54} - \left(\frac{P_2}{P_1}\right)^{1.77}}} \quad (4)$$

Generally, under production conditions, the outlet pressure of the output gas of the surface pipeline is required to be less than 2MPa after throttling. The surface throttling parameters of the gas well are calculated according to the requirements of the wellhead pressure before throttling and the outlet pressure after throttling. If the wellhead pressure is maintained at 10MPa, the higher the wellhead pressure is under the same production distribution conditions, the smaller the diameter of the selected throttling nozzle and the larger the throttling pressure drop. This shows that the small diameter throttle nozzle should be selected due to the high wellhead pressure in the initial stage of blowout. Under the condition of the same nozzle diameter, the higher the wellhead pressure, the larger the discharge volume should be adopted to achieve the purpose of throttling and reducing pressure quickly.

### 4.3. Running Time

In the production of this gas well, there are characteristics of large liquid production and high gas production in the initial stage of operation, and then the liquid production and gas production decrease rapidly and tend to be stable. Whether it is fixed production or constant pressure production, it is accompanied by pressure and gas reduction.

Gas well production can be divided into the following stages:

- (1) blowout stage. This stage has the characteristics of high gas and liquid production, and the oil pipe and gas nozzle are lowered in this stage. Due to the throttling effect of the gas nozzle, the production pressure can be maintained steadily and continuously, avoid the rapid decline of pressure, and also reduce the wellhead pressure, maintain the surface pressure operation, and reduce the risk of the surface process.
- (2) Stabilize the production stage. This stage has the characteristics of relatively stable pressure and gas production, wellhead pressure is usually reduced to about 12MPa, the use of wellhead throttling device can achieve gas throttling pressure regulation, will not produce "ice jam" situation, can be mainly tubing production, downhole throttling is not recommended to run.
- (3) Exhaustion stage. In this stage, the wellhead pressure is lower than the external pressure and the gas production is low. It is necessary to use drainage gas production and booster gas production to ensure the normal production of gas Wells. Through the above analysis, the best time to put the downhole throttle is to end the blowout test and enter the production process stage, and when the production is stable and the wellhead pressure is below 12MPa, the downhole gas nozzle can be removed to improve the drainage effect of the gas well.

## 5. CONCLUSION

To sum up, in the application of downhole throttling technology, it can be applied to the natural gas exploitation site from the aspects of throttling cooling, throttling pressure drop, throttling depth, nozzle diameter and throttling timing according to the actual situation, so as to improve the stability of natural gas exploitation.

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