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Changing Law of Flow-Field at Wellhead Under Hard Shut-In Procedure

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In view of the application status and disadvantages of well shut-in methods commonly adopted in the oil field of China, the pressure and flow velocity at wellhead under the hard shut-in procedure were simulated by finite element method. The effects of blowout preventer opening, inlet velocity and gas content on the wellhead pressure and flow velocity were investigated. The results show that the pressure at the blowout preventer is increasing significantly with decreasing of the opening, inlet velocity and gas content and the maximum pressure appears at the 10 % opening. The velocity at the blowout preventer is increasing significantly with decreasing of the blowout preventer opening and the inlet velocity, which will cause erosion destruction under long time using. The velocity at blowout preventer is decreasing with the increasing of gas content and the maximum velocity appears at the gas content of 9 %. Determining overflow in the well bottom and shutting down the blowout preventer earlier to prevent too much gas from invading into the hole and avoid causing flow velocity increase can decrease shock load on the blowout preventer effectively. Also, the shock load on blowout preventer can be decreased by shutting down the blowout preventer with adopting "fast first and slow last" shut-in procedure, which would provide guidance for the field operation.

Keywords: Hard shut-in, Simulation model, Flow field, Blowout preventer.

INTRODUCTION

In order to avoid drilling accidents such as well kick, blowout and ensure safe and efficient exploration and development, reliable well control equipments are necessary in drilling operation. In recent years, with the continuous development of drilling technology, the more and more deep well, ultra deep well and high pressure well make the risk of well blowout in oil field increase. Therefore, how to choose shut well technology to control overflow and prevent blowout becomes particularly important. Currently, soft and semi-soft shut-in are mostly used in well control process in China[1] and lots of relevant aspects of the researches have already been done. Many researchers have already done a lot of researches on the hard shut-in way[2-5] and also Xiangfang and Rong have done a lot of research in China[6-11]. However, the research on flow field simulation at the wellhead is still relatively less. Therefore, how to choose the appropriate approach has become an issue that needs to be done. Carrying out the research of the internal fluid law of wellbore under hard shut-in procedure and choosing the best approach is the key to ensure the security of the wellhead equipments.

Through the flow field simulation in different openings, velocities and gas contents, the changing law of pressure and velocity at the wellhead is studied to determine the feasibility of the hard shut-in procedure. This study will provide a theoretical reference for the subsequent water hammer simulations and provide a theoretical reference site on the hard shut-in procedures.

EXPERIMENTAL

Flow field model: In the closing process of blowout preventer, the pressure and velocity of wellhead are changing with the different openings, velocities and gas contents. Fig. 1 shows the equipment combination of oilfield and Fig. 2 shows the three-dimensional flow field model.

FE model: The former processing software ANSYS ICEM CFD was used to mesh this model. Due to the complex of this model, the tetrahedron unit was used to discrete. In order to meet the needs of the calculation precision and reducing the amount of calculation, the position of inlet, outlet and blowout preventer were setting smaller units. Fig. 3 shows the finite element model of the flow field.

Initial boundaries: In order to study the pressure and velocity at the wellhead in different conditions, analogue simulation was carried out in different openings, inlet velocities and gas contents. Table-1 shows the initial boundary conditions of this simulation.

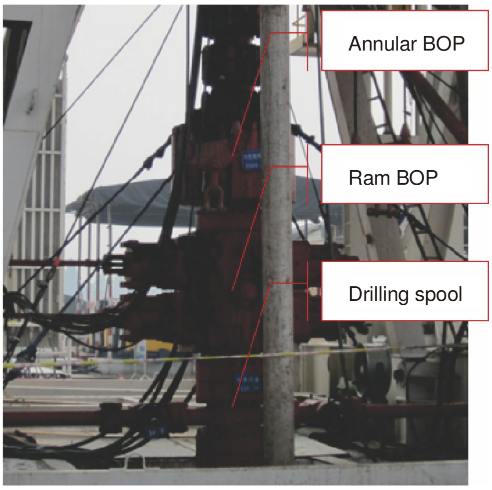


Fig. 1. Combination of oilfield equipments

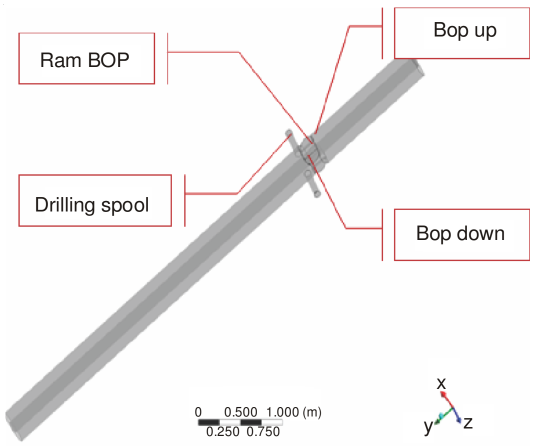


Fig. 2. Three-dimensional flow field model

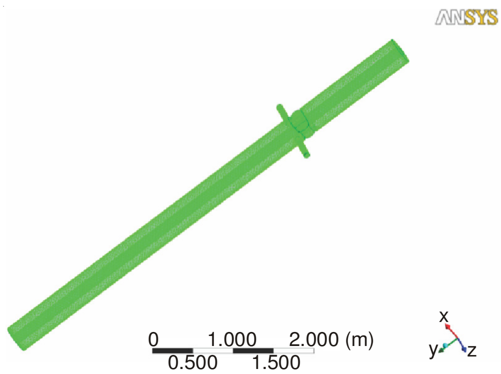


Fig. 3. Finite element model

Initial boundaries: In order to study the pressure and velocity at the wellhead in different conditions, analogue simulation was carried out in different openings, inlet velocities and gas contents. Table-1 shows the initial boundary conditions of this simulation.

RESULTS AND DISCUSSION

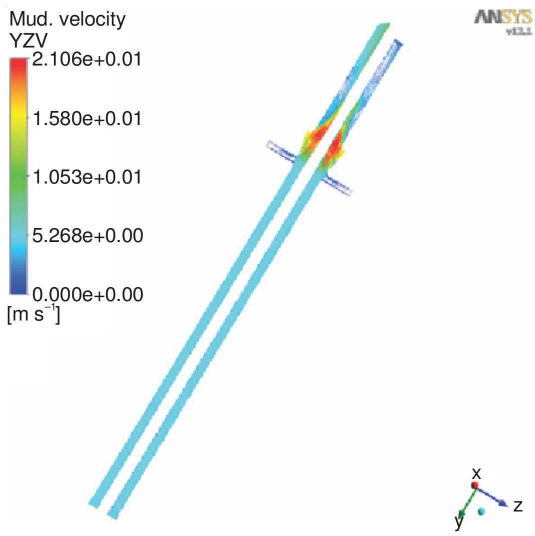
Effect of different openings on the pressure and velocity at the wellhead

Finite element simulation results: Due to the time of blowout preventer shut-in, the changing law of pressure at the wellhead in different openings was studied. Figure shows the simulation results at 10 % opening.

TABLE-1
INITIAL BOUNDARY CONDITIONS

Operating condition	Initial parameters							
Different openings	70 (%)	60	50	40	30	20	10	
	Initial boundaries	Inlet velocity: 5 m/s; Outlet pressure: 0.987 MPa; gas content: 9 %						
Different gas contents	1 (%)	3	5	7	9	11	13	15
	Initial boundaries	Inlet velocity: 5 m/s; outlet pressure: 0.987 MPa; opening: 30 %						
Different inlet velocities	3 m/s	5	7	9	11	13	15	20
	Initial boundaries	Outlet pressure: 0.987 MPa; opening: 30 %; gas content: 9 %						

Fig. 4 shows the velocity and pressure cloud map at 10 % opening. It indicates that the velocity at the blowout preventer area increases sharply with decreasing of flow area in blowout preventer position and the flow direction is closely to the surface of drill pipe and rubber core, which will cause erosion destruction under long time using. At the same time, the pressure at the lower part of the blowout preventer forms a higher-pressure region, which will cause a higher impact effect on blowout preventer.



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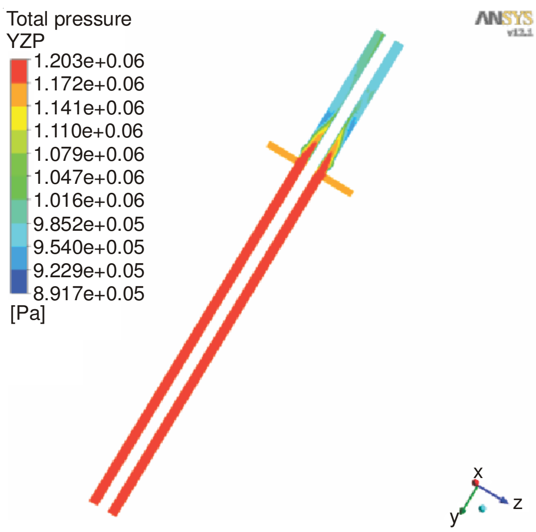


(b)

Fig. 4. Velocity and pressure cloud map at 10 % opening

Actual velocity of gas and mud in different openings: Fig. 5 shows the changing law of the gas and mud actual velocity with different openings. It indicates that the actual velocity at the up and down of the blowout preventer are both decreasing gradually with the increasing of the opening. The gas actual velocity in the down position of blowout preventer is bigger than that in the up position at the same opening, while the mud actual velocity in the up and down of blowout preventer are nearly the same. The actual velocity of gas is bigger than mud at the same opening.

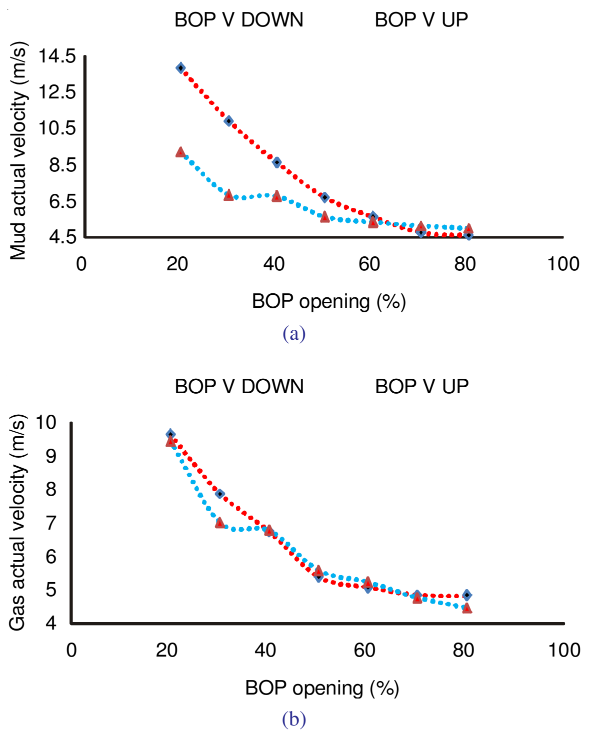


Fig. 5. Relationship between the actual velocity and the blowout preventer opening

Mixture velocity of gas and mud in different openings: Fig. 6 shows the changing law of the mixed velocity at the wellhead with different openings. It indicates that the mixed velocity at the wellhead is decreasing significantly with the increasing of the opening. The mixed velocity at the up and down of blowout preventer are nearly the same at the same opening and the maximum velocity reaches to 10 m/s at the 10 % opening, which is two times bigger than the initial inlet velocity.

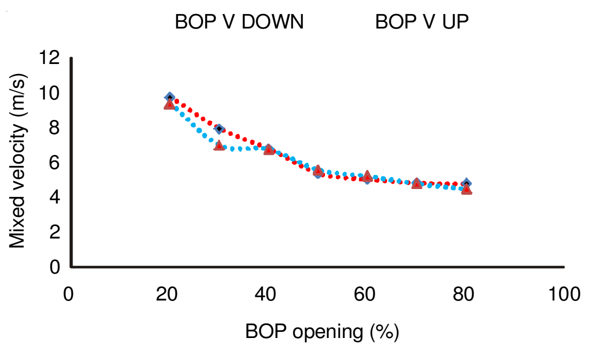


Fig. 6. Relationship between the mixed velocity and the blowout preventer opening

Pressure at wellhead in different openings: Fig. 7 shows the relationship between the pressure of wellhead and the blowout preventer opening. It indicates that the pressures at the down position of blowout preventer are increasing significantly with the decreasing of blowout preventer opening. The maximum pressure appears at the 10 % opening, which shows that the impact of the blowout preventer at the final stage of the process was the most serious. Therefore, use "fast first and slow last" shut-in process can reduce the impact on blowout preventer effectively.

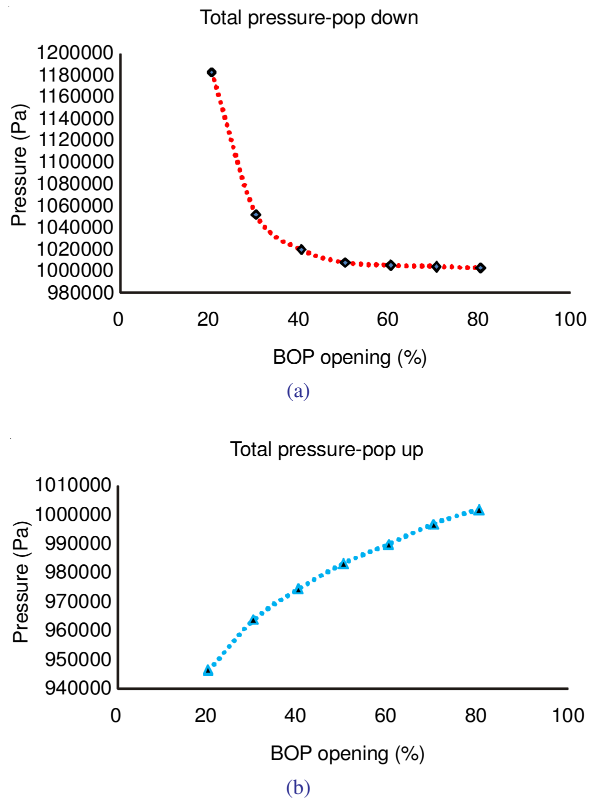


Fig. 7. Relationship between the pressure of wellhead and the blowout preventer opening

Effect of different inlet velocities on the pressure and velocity at the wellhead

Contrast of actual velocity of gas and mud at the wellhead in different inlet velocities: Fig. 8 shows the changing law of the actual velocity at the wellhead with different inlet mixed velocities. It indicates that the actual velocity of gas and mud of wellhead are gradually increasing with the increasing of inlet mixed velocity and the velocity of mud is smaller than gas. Due to the small content of gas, the impact on blowout preventer is basically formed by liquid.

Mixture velocity of gas and mud in different velocities: Fig. 9 shows the relationship between the mixed velocity and the inlet mixed velocity. It indicates that the mixed velocity is linear increasing with the increasing of inlet mixed velocity and the changing laws between the up and down of blowout preventer are nearly the same.

Pressure at wellhead in different inlet mixed velocities: Fig. 10 shows the relationship between the pressure of wellhead and the inlet mixed velocity. It indicates that the pressure of

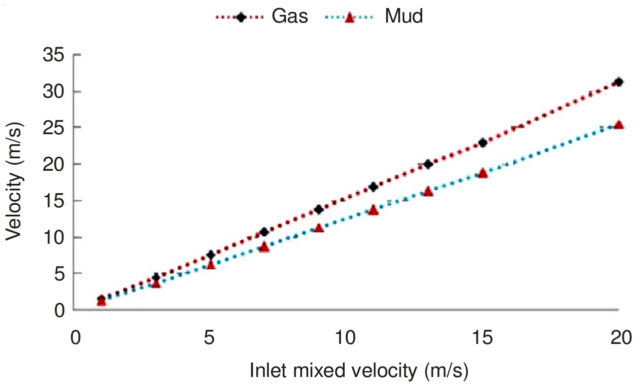


Fig. 8. Relationship between the actual velocity and the inlet mixed velocity

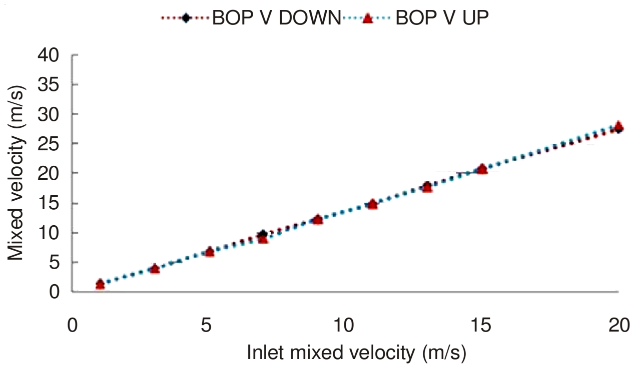
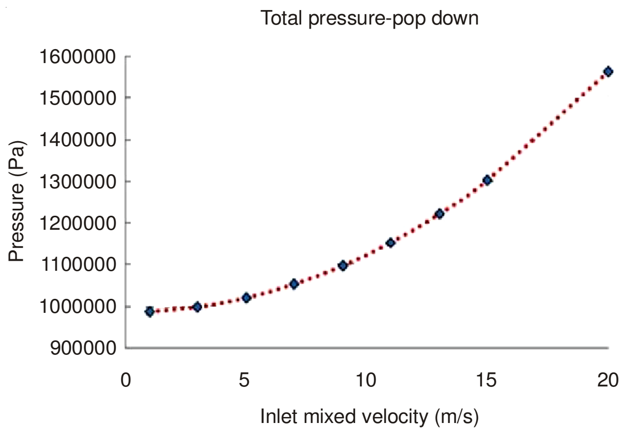


Fig. 9. Relationship between the mixed velocity and the inlet mixed velocity



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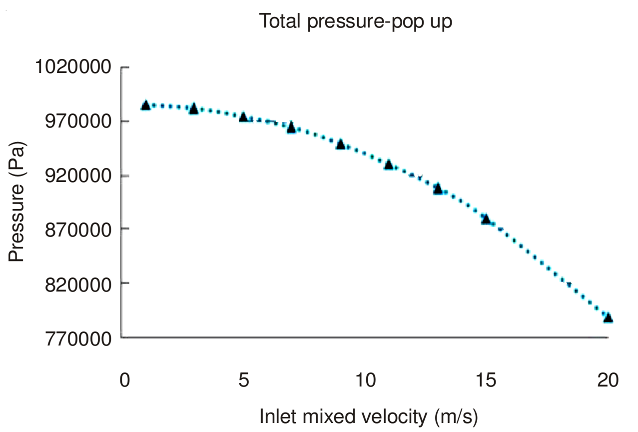


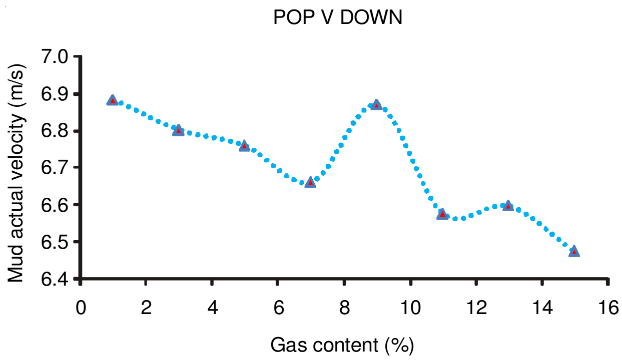
(b)

Fig. 10. Relationship between the pressure of wellhead and the inlet mixed velocity

wellhead is increasing stabilized with the increasing of inlet mixed velocity, which could directly cause the rise of impact load on blowout preventer. Therefore, detect the kick as soon as possible and close the blowout preventer in advance to prevent too much gas flow into the mud, which can effectively reduce the impact on the blowout preventer.

Effect of different gas contents on the pressure and velocity at the wellhead

Contrast of actual velocity of gas and mud at wellhead in different gas contents: Fig. 11 shows the relationship between the actual velocity and the gas content. It indicates that with the increase in gas content, the interaction between gas and liquid is enhanced as well as the energy transfer. Because of the slippage effect, the liquid transmits part of energy to gas, which causes the increasing rate of both gas and liquid velocity to drop slightly. As a result, the actual flow velocity of gas and liquid at the wellhead is gradually reduced and the gas velocity is higher than liquid velocity. Both the velocities of gas and liquid get a peak value at the gas content of 9 %, which provided guidance for the next simulation experiment.



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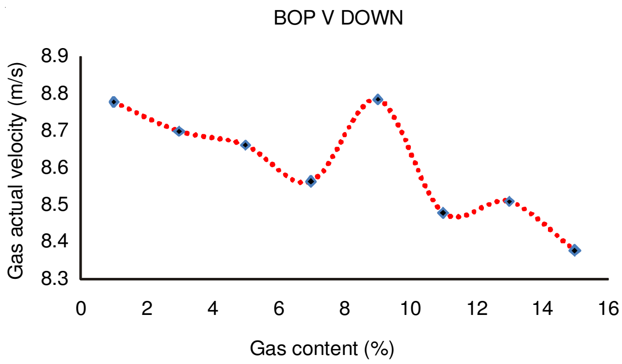

(b)

Fig. 11. Relationship between the actual velocity and the gas content

Mixture velocity of gas and mud in different gas contents: Fig. 12 shows the relationship between the mixed velocity and the gas content. It indicates that the mixed velocity is increasing with the increasing of inlet mixed velocity and the changing laws at the up and down of blowout preventer are nearly the same. This results show that the more that the gas flows into the mud, the smaller the velocity at the wellhead. Also the maximum mixed velocity appears at 9 % gas content, which will be identified though the next simulation experiment.

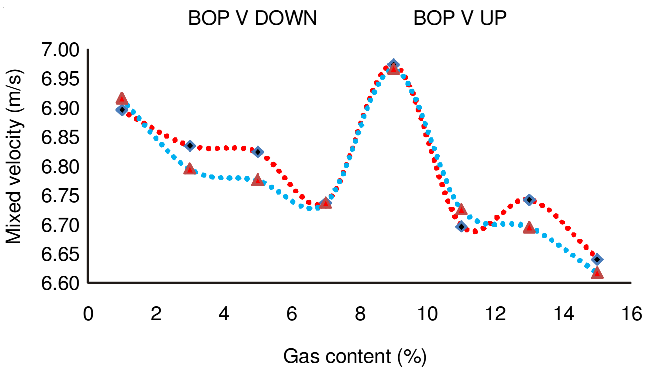

Fig. 12. Relationship between the mixed velocity and the gas content

Pressure at wellhead in different gas contents: Fig. 13 shows the changing law of the pressure at the wellhead with different gas contents. It indicates that the shock load on the wellhead decreased with the increasing of gas content, which shows that the higher gas content is, the smaller shock load and lower mixture flow velocity are, causing smaller force on shutter. However, with increasing of the gas invasion, the slippage velocity of gas increased constantly while gas moved up and the velocity of gas at the wellhead would be very high, which had a great effect on shutting well safely. As a result, determining overflow in the well bottom and shutting down the blowout preventer earlier to prevent too much gas from invading into the hole and avoid causing flow velocity increase can decrease shock load on the blowout preventer effectively.

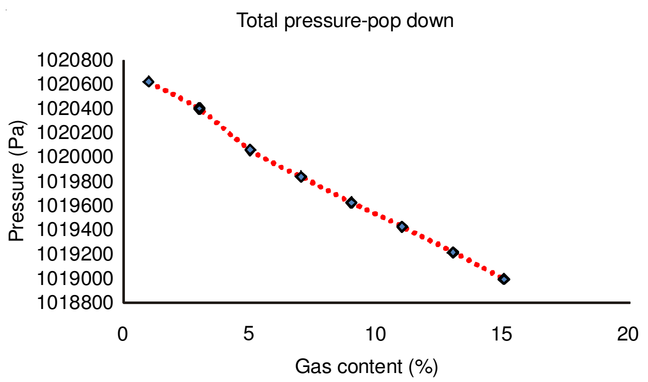

Fig. 13. Relationship between the pressure of wellhead and the gas content

Conclusion

The pressure of blowout preventer is increasing significantly with the decreasing of blowout preventer opening and the inlet velocity and the maximum pressure appears at the 10 % opening. The pressure of blowout preventer is decreasing with the increasing of gas content. The velocity of blowout preventer is increasing significantly with the decreasing of blowout preventer opening and the inlet velocity, which will cause erosion destruction under long time using. The velocity of blowout preventer is decreasing with the increasing of gas content and the maximum velocity appears at the 9 % gas content. Determining overflow in the well bottom and shutting down blowout preventer earlier to prevent excess gas from invading into the hole and avoid causing flow velocity increase can decrease shock load on the wellhead effectively. The shock load on blowout preventer can be decreased by shutting down the blowout preventer with adopt "fast first and slow last" shut-in procedure, which would provide guidance for the field operation.

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