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Research Article

The Influence of Collar on Surge Pressure Caused by the Drill String Inertia Force Under Closed Pipe Condition

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Abstract: The study of surge pressure is of significant importance for the safety of drilling process. However, the existing surge pressure models rarely take the impact of the collar into consideration and thus will inevitably affect the precision of the surge pressure calculation. In this paper, based on closed pipe condition, a steady-state calculation model for surge pressure caused by drill string inertia force is developed considering the presence of collar. In the end a case study is presented to demonstrate the importance of collar during the calculation of surge pressure.

Keywords: Casing, closed pipe, collar, inertia force, surge pressure

INTRODUCTION

During the drilling process, a constant operation is the tripping in/tripping out of a drill string in the wellbore. Due to the displacement effect of the drill string to the drilling fluid in the wellbore, an additional pressure will be generated: a pressure increase inside the wellbore due to a downward string movement is called surge pressure; while on the contrary, the pressure decrease inside the wellbore due to an upward string movement is called swab pressure. Field practice shows that the surge pressure can cause great damage to the drilling operation. Therefore the study of surge pressure is directly related to the safety of the drilling process. Excessive surge pressures may fracture weak formations and lead to a lost circulation scenario, while swab pressures may initiate a well kick or even a blowout scenario. Therefore, the accurate calculation of surge and swab pressures is of great significance for the drilling program design, the drilling accident prevention and the penetration rate improvement.

In order to meet the demand of accurately predict surge pressure in the complex wellbores, various scholars have established a series of computational models of fluid flow in the wellbore. Burkhardt (1961), Fontenot and Clark (1974) and Schuh (1964) presented the most integrated steady-state surge pressure calculation model. In these models, the impact of drill string movement on calculation of the steady-state surge pressure has been well incorporated. However, these models ignored the fluid inertia force and the compressibility of wellbore and fluid. These models are very complex and have to rely on computer programming to achieve the computation of the surge pressure.

Lubinski *et al*. (1977) initiated the dynamic surge pressure calculation model which stressed the importance of compressibility on pressure loss calculation. Lal (1983) modified the dynamic surge pressure calculation model proposed by Lubinski *et al*. (1977) and analyzed the impact of various operating factors on surge pressure (Lal, 1983). Hussain and Sharif (1997) found that the eccentricity have a great impact on the dynamic surge pressure in a recent study.

The steady state surge pressure calculation method is not as accurate as dynamic method, but due to its simplicity and accuracy to a certain extent, it is still used in some oil fields. There are four scenarios with regarding to the movement of the drill assembly: closed pipe without pumping, closed pipe with pumping, open pipe without pumping, open pipe with pumping. The literature review shows that the impact of the collar had not been taken into consideration while calculating the steady state surge pressure.

Therefore, this paper will develop a steady state surge pressure calculation model, and discuss the impact of collar on surge pressure caused by the inertia force of drill string under the closed pipe condition.

The calculation model of surge pressure caused by the inertia force of drill string under closed pipe condition ignoring collar's impact: When a drill string accelerates its movement inside the wellbore, it exerts an inertia force on annular drilling fluid. Without considering the impact of collar on surge pressure caused by inertia force of drill string, the downward movement of the drill string can be shown as Fig. 1:

According to Newton's law, the inertia force of annular drilling fluid is:

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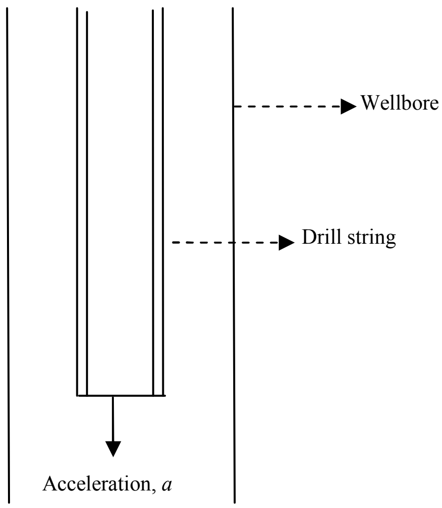

Fig. 1: Drill string downward acceleration inside a wellbore (no collar)

$$F = m\alpha \tag{1}$$

For a closed pipe

$$F = ma = \rho L \frac{\pi}{4} D_2^2 a \tag{2}$$

Therefore, when the drill string accelerates its movement, the surge pressure caused by inertia force of drilling fluid p is:

$$p = \frac{F}{\frac{\pi}{4}(D_1^2 - D_2^2)} = \frac{\rho L D_2^2 a}{(D_1^2 - D_2^2)} \tag{3}$$

where, p is surge pressure, pa; F is inertial force, N; D_1 is wellbore diameter, m; D_2 is drill string outer diameter, m; a is drill string acceleration, m/s2; L is depth, m.

The calculation model of surge pressure caused by the inertia force of drill string under closed pipe condition considering collar's impact: When considering the impact of collar on surge pressure caused by inertia force of drill string, the downward movement of the drilling string can be shown as Fig. 2:

According to Newton's law, the inertia force of annular drilling fluid is:

$$F = m\alpha \tag{4}$$

For a closed pipe:

$$F = ma = \rho L \frac{\pi}{4}(D_3^2 - D_2^2)a + \rho L \frac{\pi}{4} D_2^2 a \tag{5}$$

Therefore, when the drill string accelerates its movement, the surge pressure caused by inertia force of drilling fluid p is:

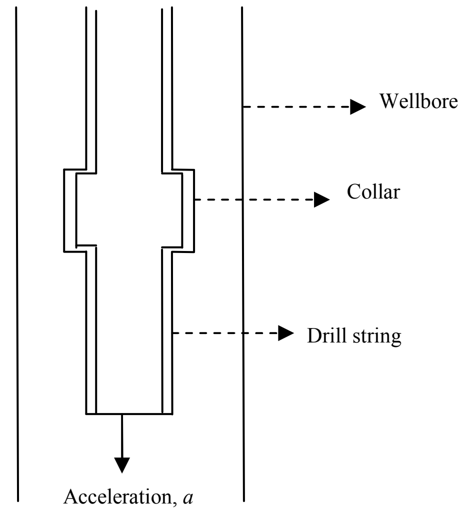

Fig. 2: Drill string downward acceleration inside a wellbore (with collar)

$$p = \frac{\rho L (D_3^2 - D_2^2) a}{(D_1^2 - D_3^2)} + \frac{\rho L D_2^2 a}{(D_1^2 - D_2^2)} \tag{6}$$

Where D_3 is collar outer diameter, m;

CASE STUDY

The measured depth is 900 m, the wellbore diameter D_1 is 215.9 mm, the casing outer diameter D_2 is 177.8 mm, the collar outer diameter D_3 is 194.5 mm, the drill string downward acceleration a is 0.15 m/s^2, the drilling fluid density is 1.3g/cm^3.

- **Consider the impact of collar on surge pressure:** From Eq. (6), it can be obtained that when considering the impact of collar the surge pressure is 494.11 kpa.
- **Ignore the impact of collar on surge pressure:** From Eq. (3), it can be obtained that when ignoring the impact of collar the surge pressure is 369.87 kpa.

The final calculation results clearly shows that when considering the impact of collar, the calculated surge pressure value is 33.5% higher than ignoring the impact of collar. Therefore, neglecting the impact of collar could cause a large error to the calculation of surge pressure.

CONCLUSION

Under the closed pipe condition, this paper developed a steady state surge pressure calculation model, and used a case study to demonstrate the impact of collar on surge pressure caused by the inertia force of the drill string. The results show that neglecting the impact of collar could cause a large error to the calculation of surge pressure, and thus could lead to down-hole incidents. Therefore, the impact of collar must be considered while calculating the surge pressure.

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