DOI 10.1007/s10553-021-01236-9
Chemistry and Technology of Fuels and Oils, Vol.57, No.1, March, 2021 (Russian Original No.1, January – February, 2021)

SURGE AND SWAB PRESSURE CALCULATION CONSIDERING CASING COUPLING

Zhong Wenjian[1], Li Guangqiao[1], Liu Biao[1*], Chen Xiuping[1], and Sun Tengfei[2]

The control of surge and swab pressure is an important guarantee to maintain the safety, cost savings, and high efficiency of well control operation, so the calculation of surge and swab pressure is very important. If the drilling speed is not properly handled, it may cause a blowout, surge and swab pressure losses, and wellbore fluid losses during the drilling process. To avoid the occurrence of complicated downhole conditions in the drilling process, the surge and swab pressure should be calculated with high accuracy. In this paper, we have considered the effect of casing coupling in the calculations of the surge and swab pressure. A case study shows that when the impact of coupling is taken into consideration, the calculated surge and swab pressure value is higher than that ignoring the coupling. Therefore, neglecting the impact of coupling could cause a significant error when calculating the surge and swab pressure.
Keywords*: surge and swab pressure, coupling, casing, closed pipe.*

INTRODUCTION

In the process of oil and gas resources exploration and development, changes in surge and swab pressure occur in the casing running process. Small pressure changes may cause significant changes in the formation permeability. Calculation of surge and swab pressure is a key problem in drilling fluid density design.

[1]Research Institute of Petroleum Engineering, Sinopec Northwest Oilfield Company, Urumqi 830011, China. [2]Beijing university of chemical technology, Beijing, 100029, China. *Corresponding author: Liu Biao. E-mail: lieren2222@126.com.* Translated from *Khimiya i Tekhnologiya Topliv i Masel*, No. 1, pp. 97 – 99, January – February, 2021.

The inaccurate calculation of surge and swab pressure may easily cause complicated conditions such as downhole overflow and well kick. At the same time, it may cause reservoir damage and reduce the efficiency of the development of oil and gas resources. Therefore, the surge and swab pressures should be accurately calculated and analyzed. When starting and running casing, downhole surge and swab pressure fluctuation should be minimized to avoid pressure abrupt changes, thus ensuring the downhole safety [1-5].

1 THE CALCULATION MODEL OF SURGE AND SWAB PRESSURE WITHOUT CONSIDERING THE CASING COUPLING

To study the effect of coupling on the surge and swab pressure, first of all, we should analyze the surge and swab calculation process without considering the coupling effect. Figure 1 illustrates the schematic diagram of the casing rate, when the casing is running down into the hole, the casing is closed, and the pump is not working.

When the casing is running down, the annulus flow rate V_f of mud consists of two parts: the mud upward movement rate V_a caused by the displacement force of the casing and the mud upward movement rate V_b caused by the adhesive force of the casing. Therefore, the annulus flow rate V_f can be expressed as [6]

$$V_f = V_a + V_b, \tag{1}$$

where V_f is the mud annulus flow rate, V_a is the mud upward movement rate, and V_b is the mud upward movement rate.

Based on the conservation law, the following equation is obtained:

$$\frac{\pi}{4} D_2^2 V_c = \frac{\pi}{4} (D_1^2 - D_2^2) V_a, \tag{2}$$

where D_1 is the diameter of the borehole, D_2 is the casing outer diameter, and V_c is the casing running velocity.

After the transformation, we obtain the following equation:

$$V_a = \frac{D_2^2 V_c}{D_1^2 - D_2^2}. \tag{3}$$

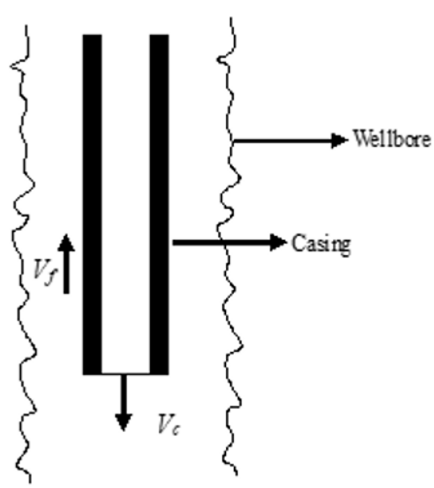

Fig. 1. The rate schematic diagram of the casing downward motion.

Buvkhardt [7-8] has put forward the relationship between V_b and V_c , and the equation is as follows:

$$V_b = MV_c, \tag{4}$$

where M is the mud adherence constant. The constant M can be determined from Fig. 2 [6-8].

Thus, we obtain

$$V_f = V_a + V_b = V_c\left(\frac{D_2^2}{D_1^2-D_2^2} + M\right). \tag{5}$$

When the casing is tripped out, Eq. (5) can be written as follows:

$$V_f = -V_c\left(\frac{D_2^2}{D_1^2-D_2^2} + M\right). \tag{6}$$

The calculation formular of surge and swab pressure is different for the laminar flow and turbulent flow of the mud.

The surge and swab pressure equation for the laminar flow, without considering the coupling effect, is as follows [9]:

$$p = \pm\frac{4KL}{D_1-D_2}\left[\frac{4(2n+1)V}{n(D_1-D_2)}\right]^n, \tag{7}$$

where p is the surge and swab pressure, L is the measured depth, K is consistency coefficient, K is 0.01 mPa.s^n, n is the flow mode index, and V is the average drilling fluid velocity, m/s. The + sign refers to the surge pressure, and the - sign means the swab pressure.

For turbulent flow, the surge and swab pressure equation without considering the coupling effect is as follows [9]:

$$p = \pm\frac{2f\rho LV^2}{D_1-D_2}, \tag{8}$$

where *ñ* is the density of the drilling fluid, g/cm^3, and f is the friction coefficient, dimensionless. The + sign refers to the surge pressure, and the - sign means the swab pressure.

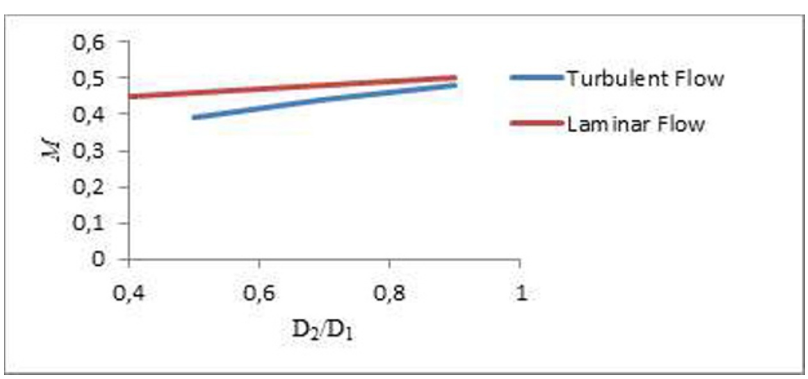

Fig. 2. Mud adhere constant.

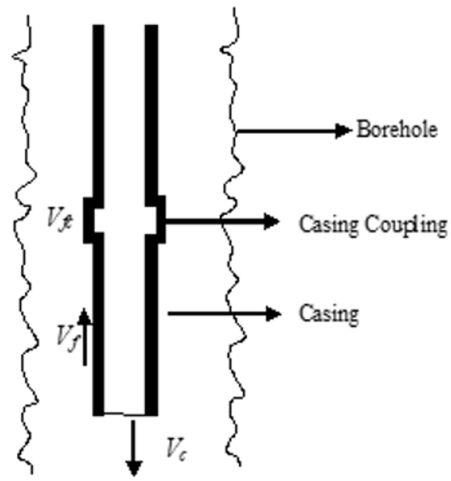

Fig. 3. Drilling fluid flow analysis considering the coupling, the pump is not working.

2 THE CALCULATION MODEL OF SURGE AND SWAB PRESSURE CONSIDERING THE CASING COUPLING

In Fig. 3, V_f is the mud annulus flow rate between the coupling and wellbore and V_{fc} is the mud annulus flow rate between the coupling and wellbore. Based on the mass conservation law, the following equation can be obtained:

$$\frac{\pi}{4}(D_1^2 - D_2^2)V_f = \frac{\pi}{4}(D_1^2 - D_3^2)V_{fc}, \tag{9}$$

where D_1 is the diameter of the wellbore, D_2 is the outer diameter of casing, and D_3 is the outer diameter of coupling.

The flow rate of the drilling fluid in the annulus of casing V_f and the flow rate in the annulus of coupling V_{fc} are both comprised of two parts: the flow rates V_{a1} and V_{a2} caused by the casing/coupling displacement force, and the flow rates V_{b1} and V_{b2} caused by the casing/coupling adhesive force.

$$V_f = V_{a1} + V_{b1}, \tag{10}$$

$$V_{fc} = V_{a2} + V_{b2}. \tag{11}$$

Based on the mass conservation law, the following equation is obtained:

$$\frac{\pi}{4}(D_2^2 + D_3^2)V_c = \frac{\pi}{4}(D_1^2 - D_2^2)V_{a1} + \frac{\pi}{4}(D_1^2 - D_3^2)V_{a2}. \tag{12}$$

From Eq. (4), we obtain the formulas to calculate the flow rates v_{b1} and v_{b2} caused by the casing and coupling adhesive forces:

$$V_{b1} = M_1 V_c, \tag{13}$$

$$V_{b2} = M_2 V_c. \tag{14}$$

After the transformation, we obtain the following equations:

$$V_f = \frac{V_c(D_2^2+D_3^2)+(D_1^2-D_2^2)V_{b1}+(D_1^2-D_3^2)V_{b2}}{2(D_1^2-D_2^2)}, \quad (15)$$

$$V_{fc} = \frac{V_c(D_2^2+D_3^2)+(D_1^2-D_2^2)V_{b1}+(D_1^2-D_3^2)V_{b2}}{2(D_1^2-D_3^2)}. \quad (16)$$

Thus, the surge and swab calculation equations based on the flow patterns are shown as follows: in the case of laminar flow

$$p = \pm\{\frac{4KL_1}{D_1-D_2}[\frac{4(2n+1)V_f}{n(D_1-D_2)}]^n + \frac{4KL_2}{D_1-D_3}[\frac{4(2n+1)V_f}{n(D_1-D_2)}]^n, \quad (17)$$

and in the case of turbulent flow

$$p = \pm(\frac{2f\rho L_1 V_f^2}{D_1-D_2} + \frac{2f\rho L_2 V_{fc}^2}{D_1-D_3}). \quad (18)$$

Considering the laminar flow in the casing and the turbulent flow in the coupling annulus, the resulting formula is

$$p = \pm\{\frac{4KL_1}{D_1-D_2}\left[\frac{4(2n+1)V_f}{n(D_1-D_2)}\right]^n + \frac{2f\rho L_2 V_{fc}^2}{D_1-D_3}\}, \quad (19)$$

where L_1 is the casing length, and L_2 is the coupling length.

3. EXAMPLE OF CALCULATIONS

The case study was used as an example to analyze the effect of coupling on the calculation results of the surge and swab pressure. The specific well data are presented in Table 1.

Table 1

Indices	Value
Well measured depth	900 m
Casing length (excluding coupling)	870 m
Coupling length	30 m
Casing outer diameter	7 in
Casing inner diameter	5.92 in
Coupling outer diameter	7.66 in
Coupling inner diameter	6.5 in
Casing running velocity	1.8 m/s
Drilling fluid flow mode index *n*	0.65
Consistency coefficient *K*	0.5 mPa.s^n
Drilling fluid friction coefficient *f*	0.008
Drilling fluid density	1.3 g/cm^3

The case study was used as an example to analyze the effect of coupling on the calculation results of the surge and swab pressure. The specific well data are presented in Table 1.

(1) The surge and swab pressure considering the coupling

Calculating, we obtain $D_2/D_1 = 0.82$ and $D_3/D_1 = 0.9$. The mud adherence constant M can be obtained from Fig. 2, $M_1 = 0.48$, and $M_2 = 0.5$. Based on Eqs. (4), (13), and (14), $V_{b1} = 0.864$ m/s, $V_{b2} = 0.9$ m/s, $V_f = 4.86$ m/s, and $V_{fc} = 8.31$m/s. Using the Reynolds number calculation equation, the Reynolds number values in casing and coupling are 11243 and 15918, respectively. Therefore, the calculated surge and swab pressure is 132.4 kg/cm^2.

(2) The surge and swab pressure without considering the coupling

Through calculating, $D_2/D_1 = 0.82 M_1 = 0.48$, $v_b = 0.864$ m/s, $V_f = 4.657$ m/s, and the Reynolds number is 3614. Based on the calculated data, the surge and swab pressure is 106.5 kg/cm^2.

The results show that the pressure calculated considering the effect of coupling is 25% higher than that ignoring the coupling.

4 CONCLUSIONS

This paper has put forward the surge and swab calculation process considering the effect of coupling, for a case of a closed pipe, when the pump is not working. The calculation results show that when the coupling is ignored, the calculation error is considerably high and may cause serious drilling accidents. Neglecting the impact of a collar may cause a large error in the calculation of surge and swab pressure. Therefore, the impact of the collar must be taken into consideration when calculating the surge and swab pressure.

REFERENCE

1. J. Lu, M. Ren, and X. Li, “Expansion characteristics of uprising gas along wellbore in deepwater drilling,” *Oil Drill. Technol.*, 39(2), 55-59 (2011).
2. X. Kong, Q. Yuan, and Y. Qui, “The research of two-phase fluctuation pressure in wellbore tripping operation,” *Inn. Mon. Petrochem. Ind.*, 5(10), 67-70 (2011).
3. A. H. Al-Ghamdi et al., “Interpretational complexities and operational complications affecting pressure transient analysis in Zuluf Field, Saudi Arabia,” *SPE Annual Technical Conference and Exhibition*, New Orleans, Luisiana, USA (2001).
4. S. L. Cohen and T. J. Hanratty, “Effects of waves at a gas-liquid interface on a turbulent airflow,” *J. Fluid Mech.*, 31, 467- 469 (1968).
5. W. C. Goins, J. P. Weichert, J. L. Burba, D. D. Dawson, and A. J. Teplitz, “Down-the-hole pressure surges and their effect on loss of circulation,” *API Drilling and Production Practice*, New York, USA (1951).
6. J. Li, Z. Huang, et al., “The influence of collar on surge and swab pressure caused by the drilling fluid viscous force under pumping condition,” *Res. J. Appl. Sci., Eng. Technol.*, 5(5), 1781-1785 (2013).
7. J. Li, S. Bi, et al., “The influence of collar on surge and swab pressure caused by the drill string inertia force under closed pipe condition,” *Res. J. Appl. Sci., Eng. Technol.*, 5(16), 4155-4157 (2013).
8. J. A. Burkhardt, “Wellbore pressure surges produced by pipe movement,” *J. Pet. Technol.*, 13(06), 595-605 (1961).
9. X. Liu, *Drilling Annulus Hydraulics and Cutting Carrying Theory*, China Petroleum University Press, Beijing, CPR (1983).