Annular Gas and Drillstring’s Transverse Amplitude

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Abstract. In drilling construction, drill string’s transverse vibration greatly improves the drill risk and complexity. Drill string is in buckling will lead it in transverse vibration, at the same time, when gas invasion appears into annular, drill string vibration will be intensified, which will create severe fatigue breakdown to drill string and improve the drill complexity. This paper has established a two-dimensional fluid-structure coupling model by CFD software to research the effect annular gas on drill string’s transverse vibration and explore the function relation between gas volume and drill string transverse amplitude. The modelling is established in static vertical interval, 1m drill string, and set the gas column length range from 88.9mm to 226.7mm to explore the law of the annular air in different well depth and transverse vibration of drill string. It can be used to predict the maximum amplitude which created by gas flowing out, so as to judge whether drill string will touch the well wall and vibrate.

1. Introduction
Field practice shows that the eccentricity of the drill string and the bending of the borehole will cause the drill string to vibrate laterally. When gas intrusion occurs, the gas will intensify the impact on the drill string's lateral vibration. From a mechanical point of view, the strong vibration of the drill string is the cause of the serious damage to the drill string [1]. The main problems caused by the lateral vibration are: the connecting thread is accelerated by fatigue and torsion; the rotation of the drill bit causes early bit failure; the bottom hole assembly is the same well The high vibration load of the wall collision caused the MWD tool to fail. After data investigation, most of the current research on drill string vibration is the analysis of drill string vibration mode and natural frequency in gas drilling or conventional drilling [2]. There is little research on the vibration of the drill string caused by gas in the annulus of conventional drilling. This article uses CFD software to model the impact of the annular air on the drill string vibration in conventional drilling, and establishes the amount of annular air and the transverse amplitude of the drill string. The function expression. CFD software is based on finite element theory [3]. It obtains numerical solutions of solid mechanics, structural mechanics, and temperature field problems by solving mechanical linear and nonlinear equations, and focuses on solving complex nonlinearities such as structure, fluid, fluid and structure coupling. problem. In this paper, the fluid-solid coupling model of the drill string and annulus fluid is established by CFD software, and the influence of the annulus air on the lateral vibration of the drill string is analysed. [4]

2. Mechanical model establishment
Because the actual working conditions of the drill string are very complicated, it is difficult to carry out accurate modelling and analysis. In view of the particularity of this research, some basic assumptions
are introduced in the analysis. The following assumptions were made when the model was established:
The axis of the borehole is a straight line; The influence of drilling fluid flow on the vibration of
the drill string is not considered, and the influence of temperature is not considered; Under the initial
conditions, the axis of the drill string coincides with the axis of the borehole; The influence of the
geometry of the coupling and joints on the drill string is not considered; The geometry of the drill bit at
the bottom of the drill string is ignored, and the bottom end of the drill string is set as the free end.

In Figure 1, the solid line represents the 1m drill string, and the dashed line represents the length of
the drill string. If there is a force acting on and drill string respectively, set the force as, and the unit is,
and the distance between the acting point and the point is, and the unit is. Then the deflection of the
bottom end of the drill string can be expressed as [5]:

\[ \omega_1 = -\frac{Fl'^2}{6EI} (3L' - l') \]  

\[ \omega_L = -\frac{Fl^2}{6EI} (3L - l) \]  

Where, \( \omega_1 \) —the maximum deflection of the bottom end of the 1m drill string after being stressed, \( m \); 
\( \omega_L \) —The maximum deflection of the bottom end of the drill string after being stressed, \( m \); \( E \) —The
modulus of elasticity of the drill string, GPa; \( l \) —The moment of inertia of the drill string cross
section, \( m \) (it is assumed that the drill string cross section is constant here).

So we can get:

\[ \frac{\omega_1}{\omega_L} = \frac{F}{F'} \frac{l'^2}{l^2} \frac{3L' - l'}{3L - l} = \lambda \frac{(3L' - l')l'^2}{(3L - l)l^2} \]  

According to the above relationship, when the gas rises in the annulus, it will produce a lateral force
on the drill string. The lateral amplitude of the force on the 1m drill string has a certain relationship with
the lateral amplitude of the drill string of length. If there may be multiple groups of gas in the annulus,
the drill string will be subjected to multiple forces at the same time. If there are multiple groups of gas
in the annulus, according to the principle of superposition [1], the combined effect of these lateral forces
on the drill string can be linearly superimposed by the effects of the individual forces. During the drilling
process, the drill string can be divided into two parts from the neutral point. The drill string above the
neutral point is subjected to tensile force, and below the neutral point is subjected to pressure.

3. Constraints, loading and solution of finite element model

3.1 Model establishment

The model structure selects the borehole size of 215.9mm and the drill pipe size of 127mm. The model
is established as a two-dimensional fluid-solid coupling model to solve the influence of the annulus air
3.2 Unit selection and unit parameters
The drill string model adopts 2-D Solid unit, the drill string elastic modulus is $2.07 \times 10^{11} \text{ Pa}$, the drill string Poisson's ratio is 0.3, and the drill string density is $7850 \text{ kg/m}^3$; the liquid phase part adopts 2-D Fluid unit, the drilling fluid density is $1200 \text{ kg/m}^3$, viscosity is $0.022 \text{ mPa \cdot s}$, the gas density is $1.8 \text{ kg/m}^3$, the viscosity is $2 \times 10^{-5} \text{ mPa \cdot s}$, the fluid gas phase unit is established by the VOF method.

3.3 Model solving
When the initial load (gas) is applied, the initial gas migration mainly depends on the pressure difference to move upward. Uneven force, when the gas moves, the gas will be dispersed, forming discrete bubbles. The tiny bubbles in the discrete bubbles will cause a part of the bubbles to settle after a certain period of time due to the low rising speed, and the gas will also diffuse in the drilling fluid. In order to obtain accurate results of the influence of the annular air on the lateral vibration of the drill string, Therefore, the transient analysis of the effect of the annular air on the drill string is used, so that the data will not be distorted. In the post-processing process, amplify the movement of the drill string, and the lateral force exerted by the air bubble on the drill string causes a certain lateral displacement of the drill string (Figure 2), and record the amplitude of the bottom end of the drill string (that is, at 1m).

4. Analysis of the relationship between annulus air body and drill string transverse amplitude

4.1 The vibration of the bottom end of the drill string at different depths when the length of the annular air column is constant
Since the model is established as a two-dimensional fluid-solid coupling model, the length of the annular air column is used to represent the amount of annular air in the study. The study found that when the air volume is constant, the distance between the annular air column and the constrained vertex is different, and the amplitude of the bottom end of the drill string changes in a certain relationship. The following figure (Figure 3) shows the amplitude of the bottom end of the drill string when the length of the annular air column is 100mm.
Figure 3. The amplitude of the bottom end of the drill string at different depths from the top of the restraint when the length of the annular air column is 100mm

4.2 Research on the relationship between maximum amplitude and air volume

It can be seen from the above that the maximum amplitude generated by the annular air body under the same air column length exists at the bottom of the drill string. For this reason, the changes in the amplitude of the bottom end of the drill string under different air column lengths, that is, the changes in the maximum amplitude, are studied. Explore the relationship between the length of the air column and the maximum amplitude as a function. Using CFD software to simulate the air column with lengths of 88.9mm (2L), 100mm, 133.35mm (3L), 150mm, 177.8mm (4L), 200mm, 222.25mm (5L), 250mm, 266.7mm (6L) The relationship between the depth and the transverse amplitude of the drill string (annulus gap 44.45mm, denoted as L). See Figure 4.

Figure 4. Comparative analysis of drill string transverse amplitude at different gas column lengths and depths

The fitting method is used to obtain the maximum amplitude that a 1m drill string can reach under different annular air column lengths.

In order to visually observe the relationship between the length of the annular air column and the maximum amplitude of the drill string, the data in Table 1 is drawn into a graph (Figure 5).
5. Conclusions

(1) This paper uses CFD software to analyse the fluid-solid coupling model of the annulus air and the drill string, and gives the functional relationship between the annulus air and the drill string lateral amplitude. This relationship can be used to calculate the gas penetration at a certain depth. The lateral amplitude generated by the string determines whether the drill string is rubbed against the well wall, thereby reducing the risk of drill string damage.

(2) During gas intrusion, formula (10) can be used to try to calculate the maximum possible amplitude at the bottom of the drill string. If the calculated amplitude is similar to the annulus gap, the amplitude of multiple sets of gas on the drill string is calculated according to the principle of superposition.

(3) The above is the influence of the borehole size of 215.9mm and the drill pipe size of 127mm on the lateral vibration of the drill string. Since the borehole size has a great influence on the drill string lateral amplitude, other conditions need to be further studied.

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