Analysis of Eccentric Wear of Sucker Rod and Design of Multi-Stage Flexibility Stabilizer

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Abstract

In the process of reciprocating motion, due to the friction between the oil pipe and the oil pipe, the eccentric wear is produced, and the service life of the sucker rod is shortened. In this paper, the reason of the eccentric wear of the sucker rod is analyzed and the mathematical model of the friction force during the reciprocating motion of the oil pumping rod is established. Multi-stage centralizer is designed according to the sucker rod eccentric wear and its movement in the process of the mathematics models of the friction force and the centralizer variable sliding friction into rolling friction, reducing the eccentric wear of the sucker rod string, increasing the service life and multistage flexible connection in the form of "dogleg" to have strong adaptability.

Keywords

Sucker rod, Eccentric wear, Friction force, Stabilizer.

1. Introduction

Along with the development of petroleum exploitation technology, the exploitation of the rod has got some development, but the oil production wells still account for more than 90% of the total number of the machines. With sucker rod using time lengthened, increase the probability of sucker rod eccentric wear phenomenon, At the same time,an increase of tubing off accidents, and the increased probability of occurrence increase the investment of equipment maintenance manpower and cost, short the service life of equipment, reduce the economic benefit of oil field. The sucker rod, tubing wear is analyzed and established between rod and tube mechanical model of friction, between rod and tube in the form of friction characteristics for design of sucker rod multistage flexible centralizer.

2. Sucker rod eccentric wear analysis

(1) the natural inclination

Due to the inclination and vertical direction in the presence of a certain angle, oil and the oil pumping rod quality component of tubing pressure, as shown in Figure 1. When the oil pumping rod moves along the oil pipe, the relative friction between the sucker rod and the oil pipe is easy to cause the eccentric wear of the sucker rod joint or the oil pipe wear and oil leakage.

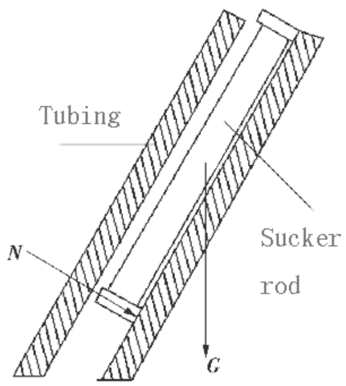


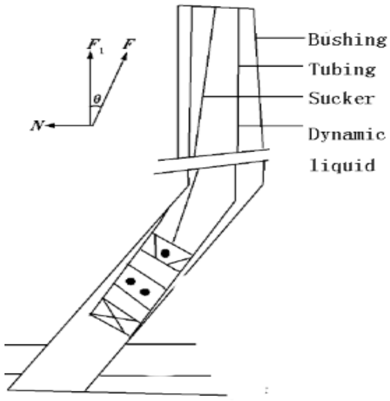
Figure 1 Schematic diagram of the natural slope of eccentric wear

(2) the deviation caused by stratum creep

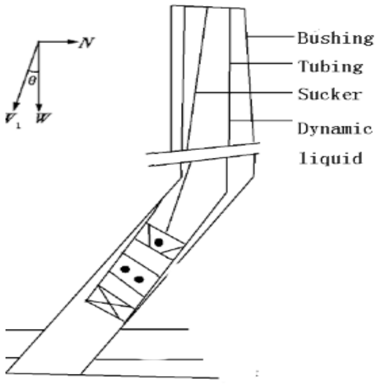
For deep well, when the crustal micro movement, the casing and tubing offset, oil wells in the vertical direction to generate a certain point of view. At this point, with the natural inclination, when the sucker rod along the exercise tubing, sucker rod and tubing between the relative friction, easy cause sucker rod joint of side abrasion failure of tubing or wear the oil spill.

(3) "dogleg" turning

First of all,what the “dogleg” is that where the sucker rod change direction dramatically. At the site of a "dogleg", when the tubing bending angle is smaller, sucker rod connected hoop and pipe friction, sucker rod reciprocating movement of the friction for single friction, and the friction surface is larger, as shown in Figure 2 (a); when the tubing bending angle is large, tubing and collar, sucker rod body between there are friction, sucker rod reciprocating movement of the friction for double side friction, and the friction surface with smaller, partial grinding speed, as shown in Figure 2 (b) as shown.



(a) Schematic diagram of the eccentric wear of the stroke on the underground pipe



(b) the sketch of the eccentric wear of the stroke under the underground pipe

Figure 2 Schematic diagram of the eccentric wear of the upper and the lower stroke of the underground pipe

(4) casing deformation

Due to crustal micro motion and deformation of downhole casing occur in the inward bulge and thus squeeze tubing with the direction of deformation, and sucker rod under the action of gravity tends to vertical. Therefore, sucker rod in the process of reciprocating motion and tubing friction, resulting in tubing leakage or sucker rod break off.

(5) sucker rod "losing stability"

The eccentric wear of the sucker rod is mainly produced in the course of the lower stroke of the sucker rod. When the sucker rod down stroke, which point above in tension, without bending eccentric wear; below the neutral point part due to the low gravity, gravity to balance various to the combined effect of the resistance, and at this time above the neutral point part with great gravity, both and mutual effect, below the neutral point of pumping rod bending eccentric wear. Because of the sucker rod has strong plasticity, the upper to lower no pressure rapidly formed, while the lower due to the inertia force of the stroke continued upward movement, to a great extent increase the bend in the lower part of the, resulting in a sucker rod's instability. In the eccentric wear of the sucker rod, the "instability" plays an important role, the degree of "instability" and the eccentric wear of the sucker rod decreases with the decrease of the neutral point.

3. Analysis of friction force of sucker rod and tube

In the course of reciprocating motion, there is a great friction between sucker rod and tubing. The calculation method of the gravity, inertia force, buoyancy force and friction force of sucker rod in the upper and lower strokes are the same.

Assuming that part of the sucker rod is flexible rod, the bending moment and shear force of the section direction of sucker rod are neglected. When the oil pumping rod is stroke, the fixed valve is opened, the swimming valve is closed, and the sucker rod drives the plunger and the liquid column upward movement. The interception of any well depth of sucker rod are analyzed, the stress diagram as shown in figure 3.

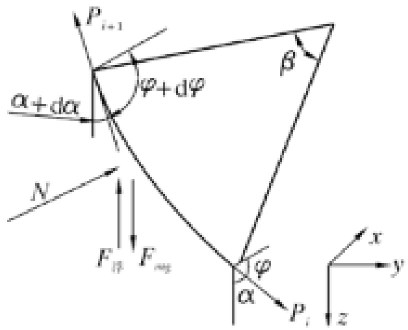


Figure 3 on the stroke of a section of pumping rod column stress diagram

(1) the weight of sucker rod string

The self weight of the sucker rod is F_{mg}

$$F_{mg} = \rho_r A \Delta L g \tag{1}$$

In the equation:

ρ_r is the sucker rod density, Kg/m^3, A is the cross section area of the sucker rod, m^3; g is the gravitational acceleration, m/s^2; ΔL presents the length of sucker rod.

(2) the rod string by buoyancy

on the sucker rod of buoyancy is named F_e, then

$$F_e = \rho_L A \Delta L g \tag{2}$$

In this equation:

ρ_L oil liquid density, Kg/m^3.

(3) Tubing support force for sucker rod.

Design tubing sucker rod support force, force of the tubing sucker rod can be decomposed into two mutually perpendicular to the plane of the component, namely "dogleg" level and "dogleg" vertical plane. The geometric relationship shows that the relationship between "dogleg" angle

$$\cos\beta = \cos\alpha_1 \cos\alpha_2 + \sin\alpha_1 \sin\alpha_2 \cos(\varphi_2 - \varphi_1)$$

$\alpha_1, \alpha_2, \varphi_1, \varphi_2$: inclination angle and azimuth angle is

Component in the plane of the "dogleg" is caused by the gravity of the oil pumping rod and axial force. According to the force balance

$$N_1 = (P_i + P_{i+1})\sin(\frac{\beta}{2}) + (F_{mg} - F_e)\cos\gamma_n$$

$$\cos\gamma_n = \sin(\frac{\alpha_1+\alpha_2}{2})\sin(\frac{\alpha_1-\alpha_2}{2})/\sqrt{\frac{1-\cos\beta}{2}}$$

P_i, P_{i+1}——Axial load at both ends of the unit section;

γ_n——The angle between the gravity vector and the shaft line method;

The force N_2 is perpendicular to the plane surface of the dogleg "caused by the gravity of the oil pumping rod, it is

$$N_2 = (F_{mg} - F_e)\cos\gamma_0$$

γ_0——The angle between the vector of gravity and the normal of the shaft;

$$\cos\gamma_0 = \sin\alpha_1 \sin\alpha_2 \sin(\varphi_2 - \varphi_1)/\sqrt{1-\cos^2\beta}$$

So

$$N_2 = (F_{mg} - F_e)\sin\alpha_1 \sin\alpha_2 \sin(\varphi_2 - \varphi_1)/\sqrt{1-\cos^2\beta}$$

Then tubing support force for the sucker rod is:

$$N = \sqrt{N_1^2 + N_2^2} \quad (3)$$

(4) The friction between sucker rod and tubing

Assume that the frictional force between the sucker rod and the oil pipe is f_1, then

$$f_1 = f|N| \quad (4)$$

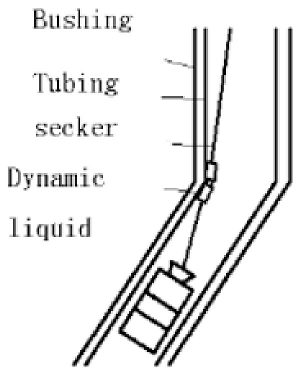
f : Coefficient of friction between sucker rod and tubing.

4. The design of multistage flexible stabilizer

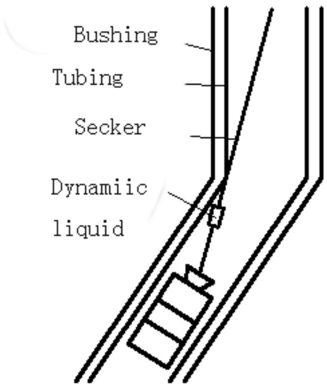
In order to reduce the eccentric wear between sucker rod and tubing, the service life of sucker rod is increased. In recent years, some research has been carried out on anti eccentric wear. Although the centralizer of partial grind to a slow down effect, but the processing quality and design structure exists many defects, different degree caused by the downhole accidents and "dogleg" change direction, casing deformation can not effectively reduce the eccentric wear of, so it failed to get comprehensive promotion. In this paper, we design a new type of multi stage flexible stabilizer, and its structure is shown in Figure 4.

Fig. 4 3D drawing of multilevel flexible stabilizer

The centralizer as the main body of the injection molding PA6 and, in the axial direction with carbon steel roller, and two centralizer body between the spring flexible connection. Access to relevant data shows that, the coefficient of sliding friction between nylon and carbon steel was 0.48, and between carbon steel rolling friction coefficient is 0.05, by formula (4) shows that by the design can greatly reduce the sucker rod and tubing between the friction and reduce the amount of eccentric wear of between the two. The flexible connection with traditional centralizer work form different, in casing deformation and "dogleg" variable to the working state and the traditional centralizer compared schematic diagram is shown in Figure 5 and Figure 6 shows.

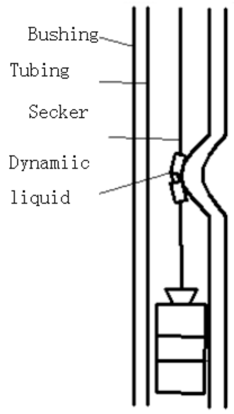


(a) to "dogleg" flexible centralizer diagram

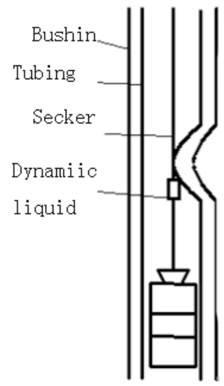


(b) "dog leg" change to the traditional centralizer diagram

Figure 5 "dog leg" change to the flexible centralizer and the traditional centralizer comparison diagram



(a). schematic diagram of flexible stabilizer in casing deformation



(b) in the casing deformation in the traditional pattern of the

Fig. 6 Comparison of the flexible stabilizer and the traditional stabilizer in the casing deformation

As figure 5 and figure 6 show, new flexible centralizer and the traditional rigid centralizer is compared, the casing deformation and "dogleg" variable to the well has a better ability to adapt, has the following advantages:

The ability to adapt to bending, deformation. Conventional rigid connections are not allowed to appear on the displacement and rotation, and flexible centralizer two connection between body can have a certain displacement or rotation. Therefore, the casing deformation and "dogleg" turn has strong ability to adapt.

Reduce friction, prevent partial wear. Figure 5 and Figure 6 shows that because of the flexible centralizer with deformability, for bending and deformation, the two centralizer body can be followed after, reduce the sucker rod and tubing between the friction and resistance card, which in a certain extent reduces the pumping between sucker rod string and tubing eccentric wear volume, increase the service life of the sucker rod string.

Buffer mutant force. Because the two centralizer body are connected by a spring, when encounter card resistance has certain buffer action, reduce the hard impact of tubing, with the role of shock absorption and noise reduction.

5. Conclusion

In this paper, combined with practice, sucker partial wear of rod causes are analyzed in theory, according to the form of the movement of the sucker rod string is calculation method of sucker rod reciprocating motion in the process of friction. In order to reduce sucker rod eccentric wear. In this paper combined with the eccentric wear causes and sucker rod reciprocating movement by friction form design of multistage flexible centralizer, the centralizer variable sliding friction into rolling friction, reducing the sucker rod and tubing between friction and using multilevel connection, increases the flexibility of the centralizer, the dogleg to change direction and casing deformation has strong adaptability.

Acknowledgements

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References

[1] Li Kun,Gao Xianwen,Tian Zhongda,etc. Using The Curve Moment and The PSO-SVM Method to Diagnose Downhole Conditions of A Sucker Rod Pumping Unit[J]. Petroleum Science, 2013, 01:73-80.
[2] Liu Xinfu, Wang Chunsheng, Liu Chunhua, et al. Mechanical model of sucker rod string based on fluid flow characteristics and its application [J]. Chinese Journal of mechanical engineering, 2013,14:176-181.
[3] Li Kun, Gao Xian-Wen, Zhou Hai-Bo,etc. Fault Diagnosis for Down-hole Conditions of Sucker Rod Pumping Systems Based on The FBH-SC Method[J]. Petroleum Science,2015,01:135-147.
[4] Wang Wenchang, di Qinfeng, Yao Jianlin, et. 3D directional wells of sucker rod string mechanics characteristics of finite element analysis method. Acta petrolei Sinica, 2010, 06: 1018-1023.
[5] Ma Jianjie, Yang Haibin, Li Hanzhou, Dai Xin. Research on the calculation method of sucker rod drilling technology [J]. neutral point, 2011,04:63-65.
[6] Wang Hanxiang, Ma Bangyong, Liu Chuanli. The establishment and analysis of the mechanical model of the horizontal well sucker rod string [J]. mechanical strength, 2009,06:952-956.