Analysis and Experimental Study on Mechanical Properties of Coiled Tubing Damaged by Slip

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Abstract

Based on the working mechanism of kava, the interaction model of kava and continuous tubing is established in view of the damage and life span of kava in holding continuous tubing. Based on the theory of elastoplastic Mechanics (using distortion energy condition), the continuous oil tube is considered as a thick wall tube to consider the internal pressure and the internal pressure. In the case of external pressure, the stress and strain problems are solved. The relationship between the depth of the continuous tubing and the suspended load is deduced, and the experimental results show that the minimum error of the experimental value and the theoretical value is 2.7% and the maximum error is 5.7%, which meets the requirements of the engineering precision.

Keywords

Slip; coiled tubing; bite depth; suspension load; error.

1. Introduction

Slip gate is a commonly used tool in oilfield development. It is an indispensable tool [1] for oil production and handling accidents. When the blowout occurs, the shear sluice in the blowout preventer quickly cuts the continuous tubing, and the kava sluice lock holds the operating oil pipe to prevent the oil pipe from falling into the well, saving the fishing time [2]. In the existing technology, if the control pressure of the kava sluice plate is small, it may cause skidding due to the lack of deep bite on the continuous tubing. If the control pressure is large, the bite mark is deep, which can cause fatigue or corrosion fatigue damage of the tubing, damage the continuous tubing to a certain extent, cause the necking in serious time, and reduce the use of the continuous tubing. Life. The kava sluice is prone to corrosion in the acidic environment for a long time, which causes the failure of the kava sluice board, and the continuous tubing will not be fixed, causing the failure of the continuous tubing falling well to cause the oil recovery accident, which will cause the damage of other equipment [3]. Therefore, it is urgent to solve and understand the interaction between the kava and the continuous tubing and give a reasonable scheme, which is one of the important factors to reduce the operation risk [4] to improve the oil recovery efficiency.

At present, scholars at home and abroad have used theoretical analysis, numerical simulation and laboratory laboratory methods to make a great deal of analysis (Research) on the material and structure design of the packer rubber tube, but basically, the study of the internal kava by the bite force between the kava and the casing has been studied. However, the research data on the occlusion of the kava and the continuous tubing are compared. Less.

Triolo MT[5] uses BDI STS-WIFI wireless structure test system for strain testing, and obtains effective data of friction and positive pressure, which provides an effective way for rubber packer experiment.

Kan Shuhua and so on carried out the finite element analysis of the kava type packer supporting kava. The results of the calculation showed that the size of the tubing and the tilt angle of the alloy support block had a great influence on the stress of the packer supporting kava [6].

Hossain and other studies have studied the surface damage of the kava drill. It is considered that it is easy to create permanent scratch on the surface of the drill string, which causes stress concentration and reduces the yield limit of the drill string, which causes the drill string fatigue to destroy [10].

Liu Tianliang and other [7] installed the kava in the simulation test device. By distributing the displacement sensor around the casing wall, it measured the depth of the casing wall after the anchoring of the kava and judged the damage degree of the kava to the casing. The results provided a theoretical basis for the optimization of the design parameters, which was very important for the design and field use of the packer. Significance.

1.1 Microanalysis of Compression of Continuous Tubing Mathematical Model

In the process of clasping the continuous tubing, the tubing can be regarded as a thick wall tube bearing the effect of the external load. When the external load is small, the material is elastic, and when the load is increasing, the material will enter the plastic deformation stage. The inner diameter of the cylinder is RI and the outer diameter is ro. The inner diameter of the cylinder is RI, and the outer diameter of the P1 external pressure P2. The distribution of the stress and strain at any point in the cylinder is symmetrical to the central axis of the cylinder, and the displacement of each point is only the component U of the R direction and the component w of the Z square, and is independent of theta. Take any cross section analysis, such as the following:

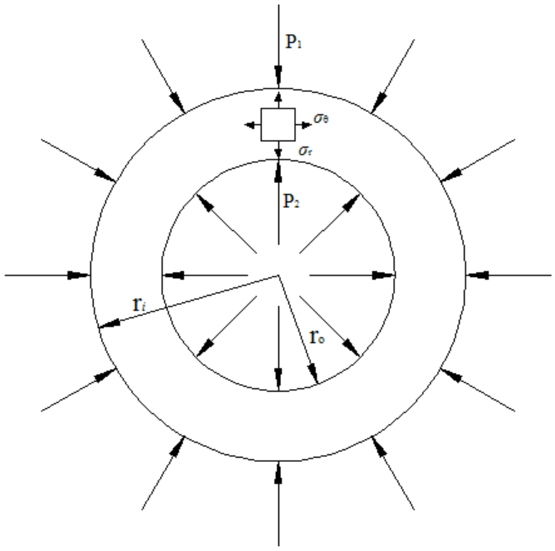


Figure 1. Microanalysis diagram of compression of continuous tubing

1.2 Elastic Solution

The strain components are respectively:

$$\left.\begin{aligned} \varepsilon_r &= \frac{du}{dr} \\ \varepsilon_\theta &= \frac{u}{r} \\ \varepsilon_z &= \frac{d\omega}{dz} \\ \gamma_{r\theta} &= \gamma_{\theta z} = \gamma_{rz} = 0 \end{aligned}\right\} \tag{1}$$

The relative volume deformation is as follows:

$$e=\varepsilon_r+\varepsilon_\theta+\varepsilon_z=\frac{du}{dr}+\frac{u}{r}+\frac{d\omega}{dz} \tag{2}$$

The strain is replaced by the generalized Hooke's law:

$$\left.\begin{aligned}
\sigma_\theta&=2G\left(\varepsilon_\theta+\frac{\nu}{1-2\nu}e\right)=\frac{2G(1-\nu)}{1-2\nu}\left(\frac{u}{r}+\frac{\nu}{1+\nu}\frac{du}{dr}+\frac{\nu}{1-\nu}\frac{d\omega}{dz}\right)\\
\sigma_r&=2G\left(\varepsilon_r+\frac{\nu}{1-2\nu}e\right)=\frac{2G(1-\nu)}{1-2\nu}\left(\frac{du}{dr}+\frac{\nu}{1+\nu}\frac{u}{r}+\frac{\nu}{1-\nu}\frac{d\omega}{dz}\right)\\
\sigma_z&=2G\left(\varepsilon_z+\frac{\nu}{1-2\nu}e\right)=\frac{2G(1-\nu)}{1-2\nu}\left(\frac{d\omega}{dz}+\frac{\nu}{1+\nu}\frac{u}{r}+\frac{\nu}{1-\nu}\frac{du}{dr}\right)\\
\tau_{r\theta}&=\tau_{\theta z}=\tau_{rz}=0
\end{aligned}\right\} \tag{3}$$

Physical neglect, at this time the equilibrium equation is:

$$\frac{\partial\sigma_r}{\partial r}+\frac{\sigma_r-\sigma_\theta}{r}=0 \tag{4}$$

The formula (3) is replaced by the upper form:

$$\frac{d^2u}{dr^2}+\frac{1}{r}\frac{du}{dr}-\frac{u}{r^2}=0 \tag{5}$$

For the upper integral:

$$u=c_1r+c_2\frac{1}{r} \tag{6}$$

Substituting the upper form (4):

$$\left.\begin{aligned}
\sigma_r&=\frac{2G}{1-2\nu}(c_1+\nu\varepsilon_z)-2Gc_2\frac{1}{r^2}\\
\sigma_\theta&=\frac{2G}{1-2\nu}(c_1+\nu\varepsilon_z)+2Gc_2\frac{1}{r^2}\\
\sigma_z&=\frac{4G\nu c_1}{1-2\nu}+\frac{2G(1-\nu)}{1-2\nu}\varepsilon_z
\end{aligned}\right\} \tag{7}$$

Taking into account the free end σ_z ==0, the boundary conditions are: $r=r_i$, $\sigma_r=-P_1$; $r=r_o$, $\sigma_r=-P_2$, Put it in the upper form:

$$\sigma_r=\frac{P_1r_i^2-P_2r_o^2}{r_o^2-r_i^2}-\frac{(P_1-P_2)r_i^2r_o^2}{(r_o^2-r_i^2)r^2} \tag{8}$$

$$\sigma_\theta=\frac{P_1r_i^2-P_2r_o^2}{r_o^2-r_i^2}+\frac{(P_1-P_2)r_i^2r_o^2}{(r_o^2-r_i^2)r^2} \tag{9}$$

$$u=\frac{1-\nu}{E}\frac{\left(P_1r_i^2-P_2r_o^2\right)r}{r_o^2-r_i^2}+\frac{1+\nu}{E}\frac{\left(P_1-P_2\right)r_i^2r_o^2}{\left(r_o^2-r_i^2\right)r} \tag{10}$$

1.3 Elastoplastic Solution

$$\frac{1}{6}\left[\left(\sigma_x-\sigma_y\right)+\left(\sigma_y-\sigma_z\right)+\left(\sigma_z-\sigma_x\right)\right]+\left(\tau_{xy}^2+\tau_{yz}^2+\tau_{zx}^2\right)=k^2 \quad (11)$$

$$k=\frac{1}{\sqrt{3}}\sigma_0 \quad (12)$$

Replace the formula (8) (9) (10) into the upper form:

$$\left(\sigma_\theta-\sigma_r\right)^2=2\sigma_0^2 \quad (13)$$

In the plastic zone, the equilibrium equation is still established:

$$\frac{d\sigma_r}{dr}-\frac{\sqrt{2}\sigma_0}{r}=0 \quad (14)$$

For the upper integral:

$$\sigma_r=\sqrt{2}\sigma_0\ln r+C \quad (15)$$

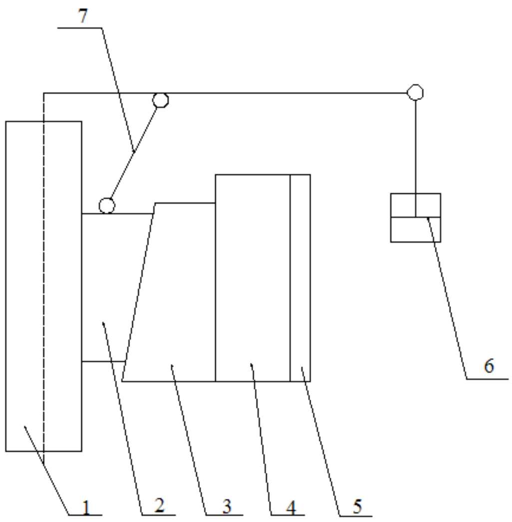
C is undetermined constant.

Then there are boundary conditions, $r=r_o$, $\sigma_r=-P_2$,

$$\sigma_r=\sqrt{2}\sigma_o\ln\frac{r}{r_o}-P_2 \quad (16)$$

$$\sigma_\theta=\sigma_r+\sqrt{2}\sigma_0 \quad (17)$$

Depth analysis of continuous tubing by slip bite



1 - continuous tubing; 2 - slip body; 3 - kava seat; 4 - bushing; 5 - shell; 6 - hydraulic cylinder; 7 - connecting rod.

Figure 2. diagram of interaction between kava and continuous tubing

1.4 Force Analysis of Kava Continuous Tubing

During the process of biting the coiled tubing, the slips can be regarded as the axial and radial compound movement along the tubing. Kava is subjected to the downward control pressure of the hydraulic cylinder to contact with the continuous tubing, and to overcome the gravity of the suspended load through the friction between the kava and the tubing, thus achieving the static equilibrium state.

$$\begin{cases} P\cos\alpha + Q - F_N \sin\alpha - \mu F_N \cos\alpha = 0 \\ P\sin\alpha + F_N \cos\alpha - \mu F_N \sin\alpha = F \end{cases} \quad (18)$$

Type: P —— the driving force of the hydraulic cylinder on the slips, MPa;
Q —— axial suspension load, N;
μ ——The friction coefficient between slips and slips.
FN——slip pedestal counterforce to kava, N;
F —— the extrusion pressure of kava to the continuous tubing, N;
α ——the oblique angle of the back cone of the kava pedestal;
By the upper solution:

$$F = P\sin\alpha + \frac{(P\cos\alpha + Q)}{\mu + \tan\alpha}(1 - \mu\tan\alpha) \quad (19)$$

Depth analysis of continuous tubing by bite of slip tooth：

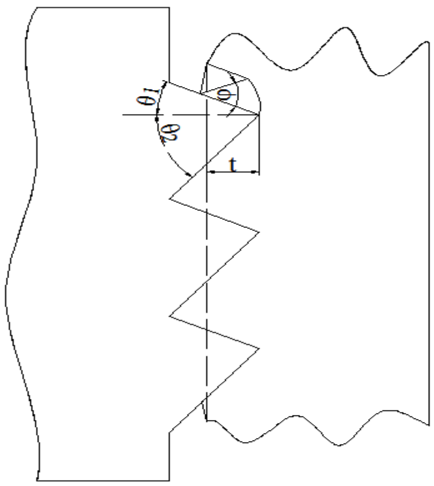


Figure 3. Depth map of kava tooth bite

The slip tooth is extruded with the outer wall of the continuous tubing, but the strength of the slip tooth is greater than that of the continuous tubing, and the tubing is first yielded, and the pressure zone [8] is formed at the biting place of the tubing.

$$\frac{F}{2t\tan\theta L\sum_{i=1}^{n} mL} = k(1 + 2\varphi) \quad (20)$$

Type: T —— slip teeth bite into coiled tubing depth, mm;
θ—— the anterior angle of the kava tooth, degree;
n—— the number of kava teeth on a single card;
ψ——the angle of the transition of the slip line of the alpha;
k——shear yield stress of coiled tubing (according to the maximum shear stress condition), MPa;
m—— the contact coefficient of the kava tooth and the continuous tubing;
L—— the expansion length of the kava tooth, mm.
Combined type (19) (20):

$$t=\frac{P\sin\alpha}{k(1+2\varphi)\sum_{i=1}^{n}mL\tan\theta}+\frac{(P\cos\alpha+Q)(1-\mu\tan\alpha)}{k(1+2\varphi)(\mu+\tan\alpha)\sum_{i=1}^{n}mL\tan\theta} \quad (21)$$

2.Slip Bite Into the Continuous Tubing Depth Test

It can be seen that the bite depth is related to the control pressure and suspension load of the hydraulic cylinder. However, in the actual analysis process, the control pressure of the hydraulic cylinder is generally negligible [9], and the formula (21) is simplified as:

$$t=\frac{(1-\mu\tan\alpha)}{k(1+2\phi)(\mu+\tan\alpha)\sum_{i=1}^{n}mL\tan\theta} \quad (22)$$

Therefore, in the process of continuous tubing descent, the kava tooth is gradually bitten into the tubing by the gravity of its own hanging load, and the wedge is tightened when the friction force reaches a certain degree.

In this experiment, the material of kava is AISI 8620 (surface gas carburizing) , and the hardness is controlled in 44HRC~48HRC. The material properties are as follows:

Tab 1. Slip related parameters

Specimen type	Modulus of elasticityE/Gpa	Poisson ratioμ	Yield strength σs/Mpa
AISI 8620	205	0.26	550

The tubing of the tubing is selected from the finished product QT800 steel grade coiled tubing with a size of 2.37 "5 x 0.156". The material properties are as follows:

Tab 2. Parameters of coiled tubing test parts

Specimen type	Modulus of elasticityE/Gpa	Poisson ratio μ	Yield strengthσs/Mpa
QT800	200	0.28	527

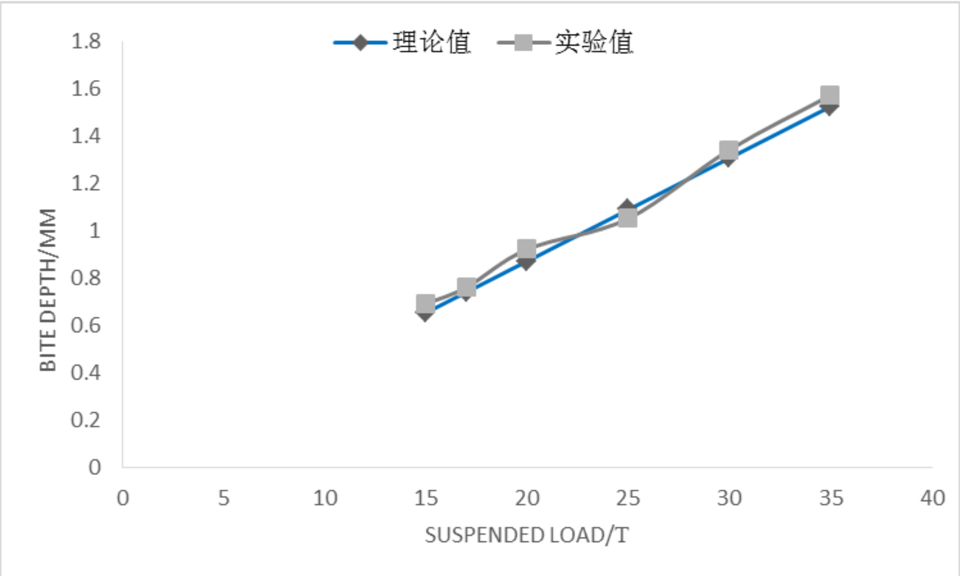


Figure 4. Theoretical value pre test curve of continuous coiled tubing under different suspension loads

When the hanging load is 15t, the theoretical value of the bite depth is 0.6525mm, the experimental value is 0.69mm, and the relative error is 5.7%. When the suspension load is 17T, the theoretical value of the bite depth is 0.7395mm and the relative error of the experimental value 0.76mm is 2.7%. When the suspension load is 20t, the theoretical value of the bite depth is 0.87mm, the experimental value is 0.92mm, relative to the experiment value. The error is 5.7%; when the suspension load is 25t, the theoretical value of the bite depth is 1.0875mm, the experimental value is 1.05mm, and the relative error is 3.5%. When the suspension load is 30t, the theoretical value of the bite depth is 1.305mm, the experimental value is 1.34mm, the relative error is 2.8%. When the suspension load is 35t, the theoretical value of the bite depth is 1.5225mm and the experimental value is 1.57mm, The relative error is 3.1%.

It can be seen that, under the given conditions, the theoretical value of the depth of the kava bite into the continuous tubing is basically consistent with the experimental value, the maximum error is 5.7%, the minimum error is 3.1%, and it is within the scope of the engineering precision.

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