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Analysis of the Depth of the Bite in the Test Packer Slipper

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Abstract: slip is the main positioning component of the oil packer. It bites into the casing to a sufficient depth to achieve positioning. Occasionally, the failure of the packer is caused by the insufficient depth of the bite in the bush. According to the slip stress analysis and structural characteristics, consider the force work and the conservation of energy of the pressurized casing, and derive the calculation formula of the depth of the oil test packer slip bite into the casing. Taking the common specifications of packer slips and bushings as an example, the MAT-LAB program for sinking the depth of the bush into the casing is prepared. Example results show that the maximum depth at which the casing bites into the casing increases with axial pressure, and non-linearly increases the axial pressure. The maximum depth at which slip bites into the casing of P110 and TP140 when the 10kN increases to 100kN. Increased by 233% and 237% respectively; under the same axial pressure, the higher the casing steel grade, the smaller the biting depth of the slip. The depth of the TP140 bushing is approximately 10% smaller than the depth of the same size P110 bushing. Therefore, when setting the packer in high grade casing, the hanging weight should be increased to ensure the positioning performance of the slip.

Keywords: oil test packer; slip; casing; bite depth; positioning.

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1. INTRODUCTION

The slip is the main positioning component of the oil packer. It bites into the casing to a sufficient depth to achieve positioning. Occasionally, the failure of the packer due to insufficient depth of the slip bite into the casing occurs. Under axial pressure, the slip moves upwards along the cone and is engaged by the cone and the casing to restrict the axial movement of the column and achieve positioning. The deeper the slip bites into the casing, the better the positioning performance of the packer, but the concentrated stress of the slip and the casing will also increase, and the bite depth will excessively damage the casing. Therefore, it is necessary to analyze the relationship between the depth of bite and the axial pressure. According to this, the appropriate set weight can be selected to ensure the positioning performance while avoiding excessive damage to the sleeve.Literature [2] reviewed the domestic packer products and technologies, summarized the packer performance test and testing equipment, summarized the calculation of the packer process parameters and the numerical simulation of related product components. In [3], considering the length and deformation of the column under the joint action of temperature, pressure, deadweight and buoyancy, a method for accurately determining the setting position of the packer is proposed.In [4], through the analysis of the principle of the free stroke generated during the setting process of the RTTS packer, the set-up free strokes of different types of packers used in different casings were calculated.Literature [5] deduced the length of the set-up string, the height of the seated and the height of the pull-out of the slip-support packer. In [6-9], the contact stress between slip and casing was analyzed using analytical, experimental and simulation methods.In [10] and [11], using laboratory experiments, the bite force in the process of slipping and casing engagement and the damage to the casing during this bite were studied. Based on the results of slip stress analysis, the paper [12] presents the optimization parameters and optimal structure of slip structures. In previous studies, people have gained some understanding of the occlusion process and occlusion force of slip and cannula, but insufficient analysis of occlusion depth of slip and cannula. This paper studies the relationship between the axial pressure and the depth of slip into the casing depth, in order to avoid the failure of the slip to make the tester positioning failure due to lack of biting depth, and to avoid the slip force over the ambassador. The strength of the casing is destroyed, while providing reference for optimization of slip structure parameters.

2. TEST PACKER SLIP BITE CASING ENERGY ANALYSIS

As shown in Fig. 1, under the axial load, the test packer slip is a composite motion in the plane (r, z) when it is set, including the upward movement along the sleeve axis and the radial movement along the sleeve.

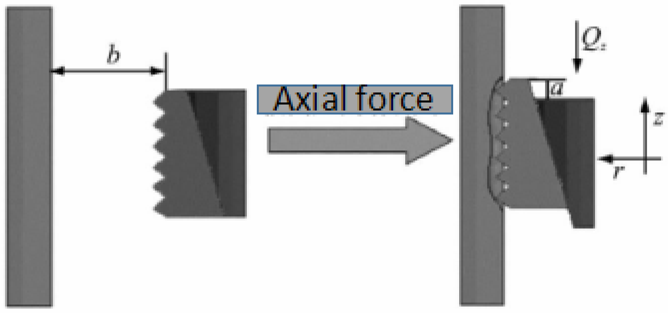

Figure 1 Test blocker slip composite motion diagram under axial pressure

It can be seen from Fig. 1 that under axial load, the displacement of the test packer slip in the axial movement takes the maximum value a, the maximum displacement of the radial movement of the casing ($b+h_x$).From the mechanical analysis of the fuel packer slip, the energy required for slip motion is:

$$E_1 = \frac{Q_Z}{n} \bullet a \qquad (1)$$

$$E_2 = \frac{Q_z}{n \bullet tg(\alpha + \varphi)} \bullet (b + h_x) \tag{2}$$

$$b = \frac{1}{2}(d_c - D_F) \tag{3}$$

In the formula E_1——the required energy of slip in axial movement, J;

Q_z——Slip axial setting load, ken;

n——Number of slip;

a——Slip movement in axial direction, m;

E_2——the required energy for the slip to move radially along the sleeve, J;

α——slip wedge angle, °;

φ——Friction angle between slip and wedge, °;

b——Slip Radial Motion Displacement;

d_c——Casing inner diameter, m;

D_F——Test packer maximum steel body outside diameter;

h_x——Slip bite into casing depth, m.

Therefore, during the setting process, the test packer slip has the energy E_k is

$$E_K = E_1 + E_2 = \frac{Q_z}{n} \bullet c$$

$$c = \left(a + \frac{b + h_x}{tg(\alpha + \varphi)} \right)$$

In the formula c——the slip equivalent axial displacement

Figure 2 is a schematic diagram of the tester packer slips biting into the inner wall of the casing. When the bite depth is h_x, the required energy E_P is:

$$E_P = \int_0^{h_x} P \bullet dx \tag{4}$$

In the formula: P——the maximum pressing force of the slip bite into the sleeve

The compression force on the sleeve P is:

$$P = \psi \bullet A_{cs} \bullet \sigma_{js} = \psi \bullet k \bullet \delta_c \bullet b_{km} \bullet \sigma_{js} \tag{5}$$

In the formula: ψ——slip tooth shape factor;

A_{cs}——the contact area between slip teeth and cannula, m^2;

k——Contact coefficient of the slip tooth and the casing, determined by the test;

δ_c——Sleeve thickness;

b_{km}——his original width of the end of the slip tooth;

σ_{js}——considering the extrusion ultimate strength of a locally extruded casing, MP.

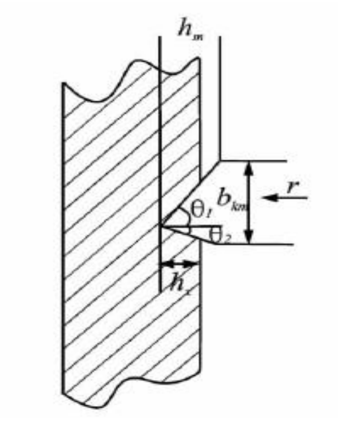

Figure 2 Schematic diagram of the test packer slips biting into the inner wall of the casing

From Fig. 2 it is known that the width of the extrusion area of the triangular slip teeth $b_{km} = h_x(\tan\theta_1 + \tan\theta_2)$; from the local extrusion test, the casing extrusion ultimate strength $\sigma_{js} = 2.5\sigma_b$, therefore, the extrusion force P is:

$$P = 2.5\psi \bullet k \bullet \delta_c \bullet \sigma_b \bullet h_x \bullet (\tan\theta_1 + \tan\theta_2) \tag{6}$$

In the formula: θ_1 ——Front angle of Slip, °;

θ_2——Posterior angle of Slip, °;

σ_b——Tensile strength of casing, MP.

Take into account the geometry of the slip tooth, Should be satisfied $60^\circ \le \theta_1 + \theta_2 \le 90^\circ$ 且 $\theta_1 \ge \theta_2$.

Substituting (6) into (4), the integral

$$E_P = 1.25\psi \bullet k \bullet \delta_c \bullet \sigma_b \bullet h_x^2 \bullet (\tan\theta_1 + \tan\theta_2) \tag{7}$$

3. TEST PACKER SLIP BITE DEPTH ANALYSIS

Under the effect of axial pressure, the energy of the test packer is used to bite a certain depth into the casing. By the principle of conservation of energy: $E_K = E_P$:

$$1.25\psi \bullet k \bullet \delta_c \bullet \sigma_b \bullet (\tan\theta 1 + \tan\theta 2) \bullet h^2{}_x - \frac{Q_z}{n \bullet tg(\alpha + \varphi)} h_x - \frac{Q_z}{n}\left(a + \frac{b}{tg(\alpha + \varphi)}\right) = 0 \tag{8}$$

Solve the equation (8) to get the slip into the casing depth h_x

$$h_x = \frac{\dfrac{Q_z}{n \bullet tg(\alpha + \varphi)} + \sqrt{\dfrac{Q_z{}^2}{n^2 \bullet tg^2(\alpha + \varphi)} + 5\psi \bullet k \bullet \delta_c \bullet \sigma_b (\tan\theta_1 + \tan\theta_2) \bullet \dfrac{Q_z}{n}\left(a + \dfrac{b}{tg(\alpha + \varphi)}\right)}}{2.5\psi \bullet k \bullet \delta_c \bullet \sigma_b (\tan\theta_1 + \tan\theta_2)} \tag{9}$$

From equation (9), it can be known that the slip bit depth and the axial pressure are non-linearly related to each other. This is due to the inconsistency in the deformation speed at the contact surface between the packer slip and the casing during the biting of the slip into the casing.

4. CASE STUDY OF SLIP BITE INTO CASING DEPTH

To visually discuss the non-linear relationship between the depth of biting into the bushing and the axial pressure, put a 5 1 /2test packer under 5 1 /2× 9.17mm P110 and TP140 sleeves, the depth of the two different grades of casing was compared with the axial pressure. Table 1 shows the design parameters of test packer slips. Table 2 shows the maximum depths of slips biting into the bushes under different axial pressures. The maximum depth of slips entering the bushing changes with the axial pressure as shown in Figure 3.

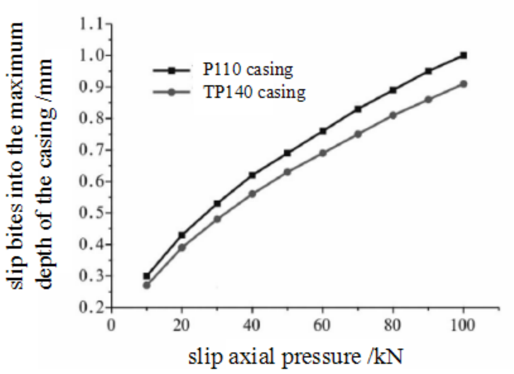

Figure 3 the curve of the maximum depth of the slip on the 5-1P110 casing and the TP140 casing with the axial pressure.

Table 1 packer parameter table

slices	thickness（mm）	Wedge angle（°）	Tooth length（mm）	width（mm）	Anterior teeth angle（mm）	Posterior angle of tooth（mm）
6	23	15	110	32	60	30

Table 2 the maximum depth of bite into the casing under different axial pressure

Axial pressure（kN）	Single chip tile stress（kN）	slip bites into maximum depth of the casing （mm）	
		P110 casing	TP140 casing
10	1.67	0.30	0.27
20	3.33	0.43	0.39
30	5.00	0.53	0.48
40	6.67	0.62	0.56
50	8.33	0.69	0.63
60	10.00	0.76	0.69
70	11.67	0.83	0.75
80	13.33	0.89	0.81
90	15.00	0.95	0.86
100	16.67	1.00	0.91

From Fig. 3, it can be seen that the maximum depth of bite into the casing is the non-linear function of the axial pressure. When the axial pressure increases from 10kN to 100kN, the maximum depth of the slip bite into the P110 casing increases. 233%, bite in the maximum depth of the TP140 casing increased by 237%. Under the same axial pressure, the slip teeth bite into the high-strength TP140 casing depth about 10% smaller than the depth of the same specification P110 casing, and the slip to the high-strength TP140 the casing is less damaged than the P110 casing. Because under the same conditions, the harder the sleeve material, the smaller the bite depth, the extrusion the greater the stress, the stronger the ability of the sleeve to resist extrusion. From the perspective of materials science, the higher the density of the material, the faster the external force forces the diffusion of the material molecules, the better the anti-extrusion performance, and the greater the energy consumption of the slip.

According to the knowledge of fracture mechanics and material science, under the joint action of formation pressure and internal pressure, the bite marks of the casing will expand plastically, and a marked concentration of stress will be generated at the bite mark tip, which will reduce the internal pressure resistance and the collapse resistance of the casing. Therefore, the set-up parameters should be reasonably controlled to reduce the damage of casing test slip slips to the casing.

5. SUMMARY

The energy equation was used to derive the depth equation for the bite-inserted casing of the test-seal packer slip, and the depths of the two material casings that the slips bite into the P110 and TP140 under the same axial pressure were compared and analyzed. The following conclusions were obtained:

(1)Derived the relationship between the depth of the biting sleeve and the axial pressure.

(2)The maximum depth of the slip bite into the bushing increases non-linearly with increasing axial pressure and the axial pressure increases from 10kN to 100kN, the maximum depth at which the slip bite into the P110 casing increases by 233%, and the maximum depth at which the bite into the TP140 casing increases by 237%.

(3)Under the same axial pressure, the slip teeth bite into the high-strength TP140 casing depth is less than the depth of bite into the same specification P110 casing, slip is less than the P110 casing in the high-strength TP140 casing damage, in the high-grade steel sleeve When the packer is installed in the pipe, the hanging weight should be appropriately increased to ensure the slip positioning performance.

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